AMERICAN COMPOUND LOCOMOTIVES

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American Compound Locomotives

A PRACTICAL EXPLANATION OF THE CONSTRUCTION, OPERATION AND CARE OF THE COMPOUND LOCOMOTIVES IN USE ON AMERICAN RAILROADS

BY

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As the result of rebuilding the little Baxter engine on the Worcester & Shrewsbury Railroad, about thirty years ago, my father,

HENRY F. COLVIN,

became an advocate of the compound locomotive. His suggestions and designs have materially aided in the development of this type of locomotive, and his friendly counsel and criticism have been of great assistance to the author in preparing this work. To him this book is affectionately dedicated.

A Bit of History.

The principle of compounding steam engines, which was invented by Jonathan Hornblower in 1796, was practically unused in any form until Thomas Craddock began experimenting with a compound locomotive in April, 1844. Four years later (1848) he published a book called "The Chemistry of the Steam Engine," in which he announced his belief in the practical superiority of the compound feature and described his engine therein. This had but one eccentric, one valve, one crosshead, one connecting rod, and one steam box to serve both cylinders on one side.

As the illustration of his first compound locomotive shows two crossheads and two rods, he evidently decided that the fewest parts did not always mean the best machine. He still used but one valve, however, and had a fan condenser, claiming a vacuum of 24 inches. The cylinders were 6 and 14 inches in diameter, which gave a ratio of 1 to 5.44, much larger than is used at present. He used a pressure of 115 pounds, but was confident that a much higher pressure would be adopted in the near future. He named 200 pounds as probable, but it was many years before this became at all common.

John Nicholson invented a compound locomotive

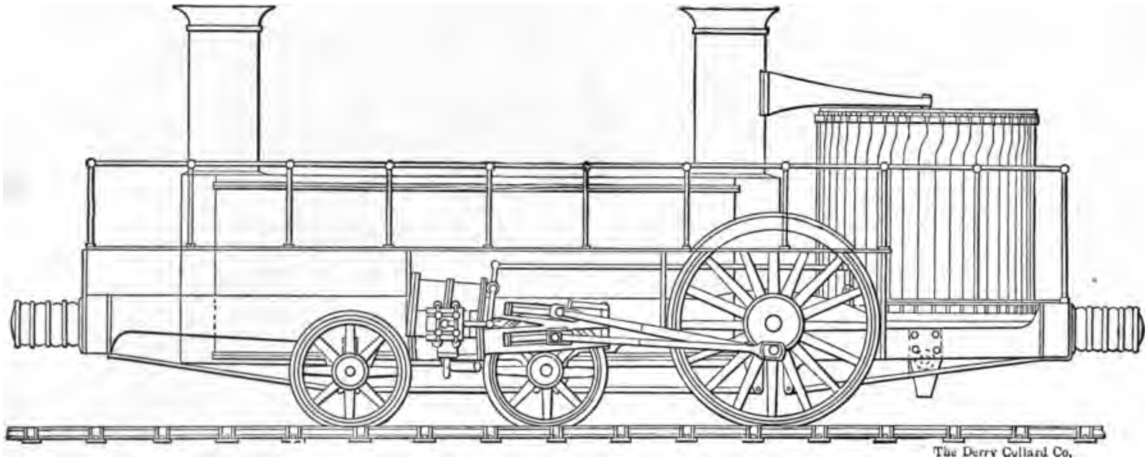


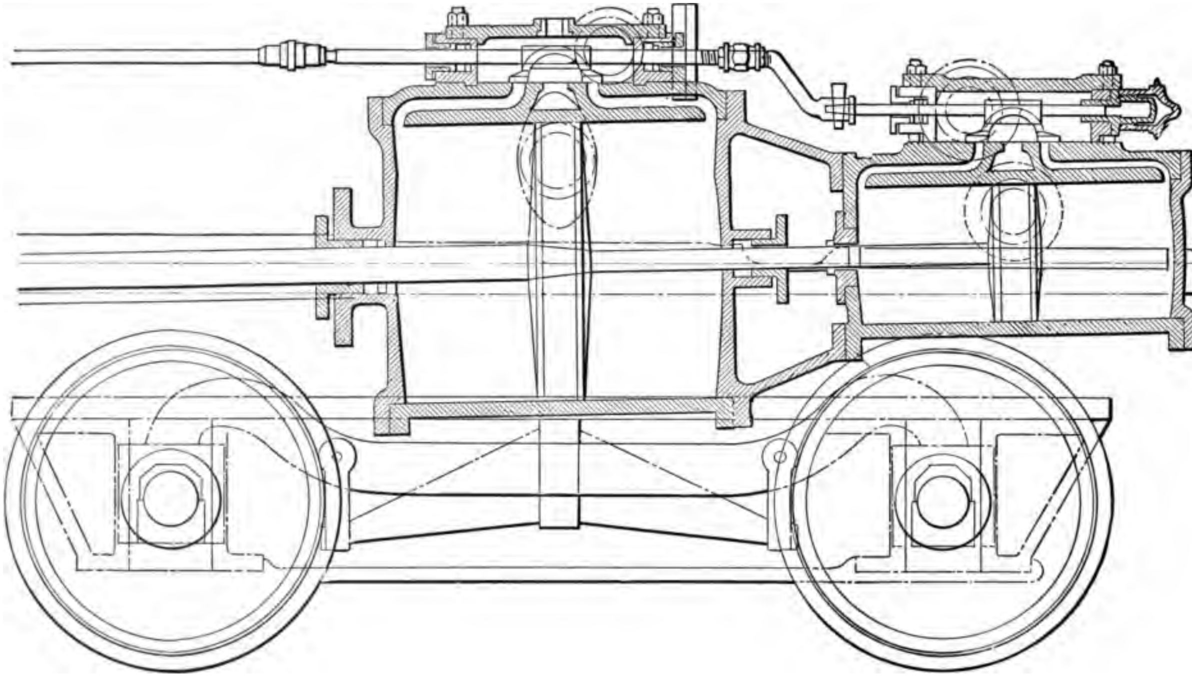
Figure 1. First compound locomotive. Craddock, 1848.
Four cylinders and condenser behind.

in 1850, using the very small ratio of 1 to 1.36, the cylinders being 15 and 17½ inches in diameter. There was no receiver, and each cylinder had its own valve. It is credited with saving 20 per cent. in fuel, which was coke in this case. This seems a very large saving considering the small difference in cylinders.

James Samuels also patented a compound locomotive this same year, his bearing date of April 5th. Among his claims were "cranks at right angles, or nearly so, and with two or more cylinders," but his engines seem to have been built on the two-cylinder type. He used an intercepting valve and could work the engine simple, each cylinder having a communication to the exhaust. Some of his engines also had a hollow valve which conveyed the high pressure exhaust through it to the steam chest of low pressure cylinder.

Frazer Selby, County Surrey, England, patented a compound engine having annular cylinders (high pressure cylinder inside of low pressure) on September 9th, 1862, and also other types of four-cylinder compounds. This was the forerunner of the Johnstone compound, built for the Mexican Central Railroad in 1892 by the Rhode Island Locomotive Works.

The first compound locomotive in this country was an engine of the Erie Railroad, which was changed to a tandem compound at the Shepard Iron Works, Buffalo, in 1867, according to designs of Perry and Lay. The illustration shows how a 12-inch high pressure cylinder was placed ahead of a 24-inch low pressure cylinder, giving a ratio of 1 to 4, which was too high for the steam pressures then in use. The stroke was 24 inches. Both valves were moved by one stem, which was unfortunately bent as shown. The method of mak-



The Derry Collard Co.

Figure 2. First American compound. Perry and Lay, 1867.

ing one gland pack the piston rod between the cylinders is worth noting. The bushing extends from one cylinder to the other, and makes a simple way, which is being adopted on the modern tandems.

The engine ran well and did good work, but as coal economy was not then a vital question, no more were built.

In 1870 the Remington Arms Company of Ilion, N. Y., built several two-cylinder compound locomotives from the designs of William Baxter. One of these was sent to the Worcester and Shrewsbury Road and is reported to have given good service. The principal objection found was that, there being no reducing valve, the power was very unequal when worked simple. The intercepting valve was under the control of the engineer, so that it could be run simple or compound for any length of time necessary. This was the first compound in this country to have the intercepting valve on the high pressure side.

What is sometimes referred to as the first two-cylinder compound is the patent of William S. Hudson, of the Rogers Locomotive Works, Paterson, N. J., in 1873. In reality this patent was for a re-heater located in the smoke-box of a compound locomotive, for re-heating the steam as it passed from the high pressure cylinder to the low. As none were built, it will be seen there was no such thing as the Hudson compound locomotive.

It is neither profitable nor desirable to follow all the patents that have since been issued on compound locomotives. Those mentioned show the origin of the different types and from these the present compounds have been brought to their improved condition. Those

who wish to follow the design and experience of the various types can do so in various proceedings or transactions of the different engineering societies. It is well, however, before passing to the modern American compound locomotives, in which we are most interested, to glance at the leading types of foreign compounds. Taken in the order of their construction they are as follows:

Anatole M. Mallet (French) patented an engine with two tandem cylinders, central between frame and under smoke-box, in October, 1874. This had a slide valve in a chest outside the smoke-box, the stem extending to cab, and being under control of the engineer. With this valve in one position, boiler steam could enter the low pressure cylinder when the exhaust from the high pressure cylinder is escaping to the atmosphere. At the same time boiler steam is entering the high pressure cylinder as usual when the throttle is open.

In the other position no boiler steam can enter the low pressure cylinder, but the high pressure exhaust was directed to the low pressure cylinder, instead of the stack. At the same time the low pressure cylinder was exhausting direct to the atmosphere.

A small pop valve was placed on the steam passage to low pressure cylinder, where the engineer could see when it blew off, and then reduce the amount of boiler steam going to the low pressure cylinder. This valve was loaded to from 40 to 50 per cent. of boiler pressure.

Two years later he built three tank engines of the two-cylinder type, having a high pressure cylinder 9.45 inches and the low 15.75 inches, making a ratio of 1 to 2.78. The stroke was 19.72 inches, and the pressure 150 pounds. Both cylinders were outside the frames.

There was a separate exhaust for the high pressure cylinder, and in starting he admitted wire-drawn steam to the low.

He realized the weak points of this method, however, and designed a self-acting reducing valve, which for some reason failed to give satisfaction. This seems to be the first instance where this was tried, and the successful working of the reducing valves used to-day indicates something wrong in his design or construction.

The well-known "Webb" type of compound was patented by Francis W. Webb early in 1881, and has two high pressure cylinders outside and connected to the rear drivers. Inside the frames and under the smoke-box is the low pressure cylinder, which is connected by cranked axle to the front drivers. The exhaust from both high pressure cylinders go to this one low pressure cylinder, and as there are no side rods, each pair of wheels is independent. But one of these has been used in this country, the Pennsylvania Railroad importing it in 1889. It did good work, considering its weight and steam pressure, and made a good showing on fuel. His latest engines have two low pressure cylinders, and are balanced engines.

The Von Borries engine (August Von Borries, Hanover, Prussia, 1887) is very similar to the Mallet, being a two-cylinder compound locomotive with an intercepting valve. This is placed next the low pressure cylinder, and was made to operate automatically by receiver pressure in 1887. For starting, he admitted live steam to low pressure cylinder through a small pipe to wire-draw it. He has never used reducing valves, and the engines go into compound automatically as soon as the receiver pressure reaches a pre-determined point.

This prevents the engine being run simple except for the first few revolutions.

The Worsdell compound (Thomas W. Worsdell, England), same date as Von Borries, is almost identical in the important details. His patents specified a "flap valve" as being preferable for an intercepting valve. No reducing valves are used, and it has the same objection as the others.

In 1889 Robert Lindner (Chemnitz, Saxony) patented (in England) a two-cylinder compound in which the reverse lever controls the admission of live steam to the low pressure cylinder. As the engine gets under way and the reverse lever is moved nearer the center (or "hooked up"), the live steam is cut off from low pressure cylinder, and when finally closed, the engine goes into compound.

J. Lewis on June 11, 1889, was granted a United States patent for a compound, which in some ways reminds us of the Vauclain engine.

There were four parallel cylinders, and the high and low pressure cylinders on each side were connected to one cross-head, with one connecting rod to crank pin. Here the marked similarity ends, as one rotating elastic valve, centrally located, controlled the steam to all four cylinders. Boiler steam was admitted to the low pressure cylinders for starting, under control of the engineer.

Another patent, which had two cylinders connected to one crosshead, was that of Richard H. Lapage, 1890 (both United States and English). This was for a three-cylinder engine, with the two low pressure cylinders connected in this manner on one side, the high pressure being on the other side. This was done to re-

duce the total width of the engine, as this was one of the objections raised to the two-cylinder compounds at that time. This objection proved groundless, however, and none of these were built, in this country, at least.

This brings us to what may be called modern practice, and without going into the history of each make now in use, they will be described and explained as clearly as possible. Before doing so, however, it may be well to touch briefly on the theory or principles on which compound locomotives are constructed.

Theory of Compounding Steam Cylinders.

The theory of compounding the cylinders of any engine, stationary or locomotive, is to direct the exhaust steam from the high pressure cylinder to the steam chest of the low pressure cylinder, instead of allowing it to escape directly to the atmosphere with all its heat and energy. This divides the expansion between two cylinders, and in so doing makes a smaller drop in temperature in each, which avoids excessive condensation and secures the desired expansion without too short a cut-off. With an initial pressure of 200 pounds to the square inch and an expansion which brings the exhaust down to 5 pounds, there is a drop in temperature from 387 to 227 degrees, or a difference of 160 degrees. This drop in temperature cools down the walls of the cylinder, which must be warmed up again by the incoming steam, and this is what causes the condensation and loss.

By dividing the expansion of steam between two cylinders and allowing it to drop to 75 pounds before going to the low pressure steam chest, the temperature in the high pressure cylinder is only reduced to 320 degrees, a drop of but 67 degrees, instead of the whole 160 degrees in one cylinder. This means that the in-

coming steam does not meet such cool walls as before, and the condensation is, of course, correspondingly less.

In the low pressure cylinder the steam is expanded down to say 5 pounds, and the drop in temperature here is from 320 to 227 degrees, or 93 degrees. These pressures are not necessarily the adopted practice of any system of engines, but merely taken to show the principles involved. In reality they depend on the size of the cylinders or the ratio of one to the other, so as to have each side of the engine do approximately equal work. Too much stress is often laid on this, however, as in actual service it makes little difference whether the work is exactly equally divided or not. Few simple engines divide the work up exactly even, especially after the cylinders have been rebored, and the instances where an engine has been run in "one-sided," often with its train too, are too numerous to mention.

The object of compounding, then, is clearly to save steam, which means both fuel and water, or to accomplish more work with the same amount of both.

In designing, however, it is customary to calculate dimensions and pressures, so as to even up the work as closely as possible, and a glance at the way of doing it may be of interest. In this case the high pressure cylinder received steam at 200 pounds pressure, and exhausted to the low (either through a receiver or direct, according to the ideas of the designer) at 75 pounds. Neglecting expansion for easy figuring (that is assuming the steam to follow full stroke at boiler pressure) we have the forward pressure of 200 pounds and a back pressure of 75, leaving a mean or net forward pressure of 125 pounds. In the low pressure cylinder we have 75 pounds less the back pressure of 5 pounds,

or 70 pounds net pressure pushing the piston ahead. If these pressures were correct (which they are not, owing to expansion being left out of the question), the proper cylinder ratio would be 125 divided by 70, or 1.78, meaning the area of the low should be 1.78 times that of the high. With this ratio a 20-inch high pressure cylinder would only have a 26½ low pressure cylinder, when in reality common practice gives about 2¼ to 1, which would give a 30-inch low pressure cylinder for a 20-inch high. Four-cylinder compounds sometimes use a larger ratio, 2½ to 1 being quite common, and 3 to 1 being used in some cases, the pressures being regulated to suit by varying cut-off in the cylinders.

When compounds first began to make their appearance, some had the impression that the steam used in the low pressure cylinder was all gain, overlooking the fact that the steam used in the low pressure cylinder is back pressure on the high, and that the saving in steam comes from the prevention of condensation. The saving in fuel is due both to this and to the softer blast on the fire. This plays a more important part than is sometimes considered, for being at a lower pressure than in a simple engine, the speed is slower, and it approaches a continuous blast, which gives better combustion and does not throw as much unburned fuel out of the stack.

Baldwin Two-Cylinder Compound.

These engines were designed for the Norfolk and Western Railroad, and like the Pittsburg engine, have the intercepting valve on the high pressure side, so that it is independent of receiver pressure.

The intercepting valve is somewhat similar in action and appearance to that of the Pittsburg engine, consisting of two heads connected by a substantial rod, so that both always move together. The spring shown at the left holds the valve in simple position as in Fig. 3, unless the engineer wishes to run compound.

In simple position, the steam from boiler goes to high pressure cylinder, where shown, and acts on the end of reducing valve R, opening it and allowing live steam to flow into receiver. The very crooked passages from the receiver to the back of reducing valve allows this to act on the larger area of the valve, and the pressure is reduced so as to give the low pressure piston the same power as the high when running simple. The exhaust from the high pressure cylinder passes through intercepting valve between the heads and out of the independent exhaust, while the low pressure exhaust direct to stack as usual.

The operating valve in cab is simply a three-way cock, which in simple position opens both pipes marked

D to the atmosphere, and allows the spring to close the intercepting valve and the reducing valve to act as already described. Turning the operating valve to compound position, admits steam to the pipes D and forces intercepting valve to left, as well as closing re-

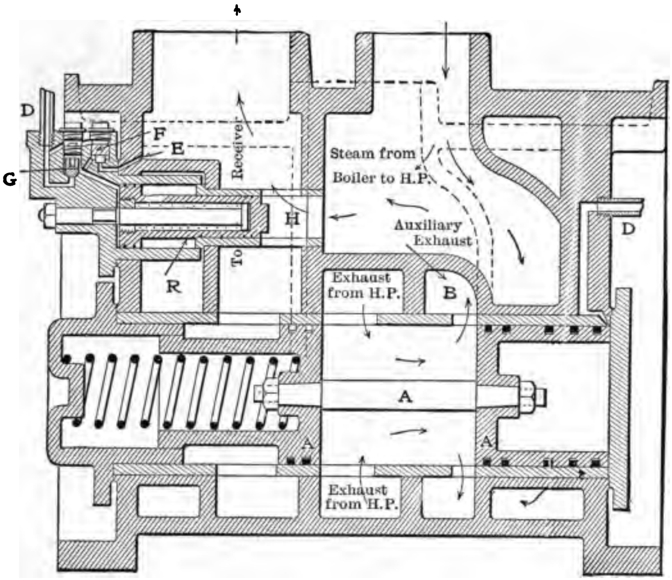


Figure 3. **Baldwin two-cylinder compound in simple position.**

ducing valve by boiler pressure on large area through pipe D and check valve G.

In this position the high pressure exhaust passes between the heads of intercepting valve and direct to

receiver, then to low pressure steam chest. The reducing valve is closed, and no live steam gets into receiver or to low pressure cylinder. This condition is plainly shown in Fig. 4.

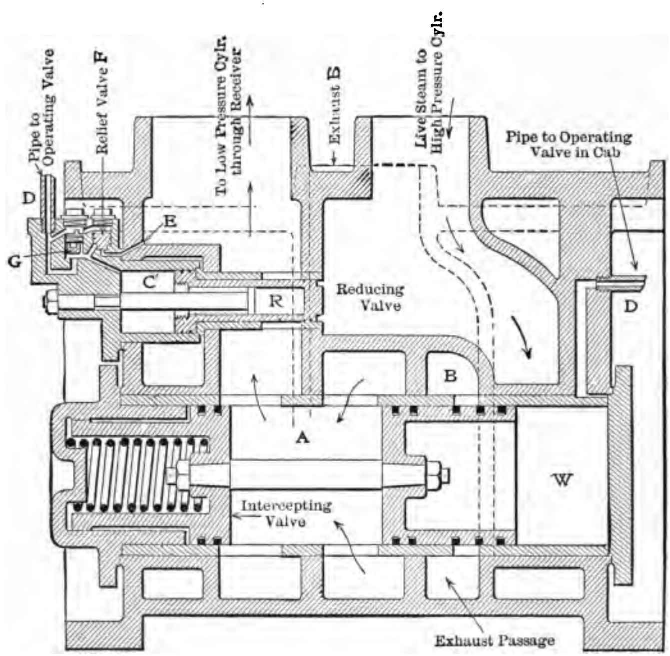


Figure 4. Baldwin two-cylinder compound in compound position.

Breakdowns with this type of compound can be handled the same as with the Pittsburg engines, both differing very little from simple engines in this respect. Remember that it is necessary to keep the steam out of the broken side. If this is the high pressure side,

the valve of that cylinder must be blocked to cover ports, and the engine can then be run with operating valve in simple position, as this will admit live steam through the reducing valve to the low pressure cylinder.

Should the low pressure cylinder be disabled, the steam must be kept out of that cylinder. This can be done by first putting operating lever in simple position, which will throw intercepting valve to the right under action of the spring. Then close the cock in pipe between the cab and the end of intercepting valve, which will prevent steam affecting this valve in the least. Now throw the operating valve into compound position, which will admit steam behind reducing valve and close it, so that no steam can get to low pressure from any source. It can then be run with high pressure side as long as necessary.

Sometimes the pop valve in front of smoke arch, which is to relieve an excess pressure in the receiver, will blow, indicating that possibly the reducing valve is not just as it should be. If this continues, remove the small cap next the saddle on the reducing valve end and see if valve is stuck. If so, free it, as it interferes with reducing valve action. If this is all right, the trouble is probably in the pop valve, which is either stuck or broken. This will only be noticed when engine is working simple.

Should engine refuse to work in simple position, the intercepting valve cover should be removed and the valve pushed clear back in cover. Then remove cap over reducing valve, and see this valve works freely, when it can be replaced. If, after putting all parts back into place, it still refuses to work in simple posi-

tion, take off front cover of intercepting valve and push valve clear; then replace and proceed.

Practically the same thing is to be done if it refuses to work in compound position. Remove covers and free the valves, if stuck. If this does not remedy the difficulty, the engine can be run simple, taking care to work as light a throttle as possible, if the reducing valve is not acting as it should. Otherwise the low pressure cylinder will receive full boiler pressure of steam, and be very apt to damage that side of the engine at least.

Pittsburg Two-Cylinder Compound.

This differs from most of the other two-cylinder compounds in a number of details, and though only a comparatively small number have been built, they have been very successful where used. It is the invention of Henry F. Colvin, of Philadelphia, and was patented on May 27th, 1890, and November 24th, 1891.

This was the first of the modern compounds to have the intercepting valve on the high pressure side, and is the only one so placed, except the two-cylinder compound built by the Baldwin Works for the Norfolk and Western Railroad. This makes its movement entirely independent of the receiver pressure, so that it cannot go into compound automatically from the accumulation of receiver pressure, as do some of the others.

It is at all times under the control of the engineer, who ought to know better than any automatic device when the engine should be run compound and when simple. Some of these have been made with an attachment to the reverse lever, so arranged that the engine is always in simple position when the reverse lever is in full stroke notch, but is thrown into compound as soon as the engineer begins hooking up. This is a

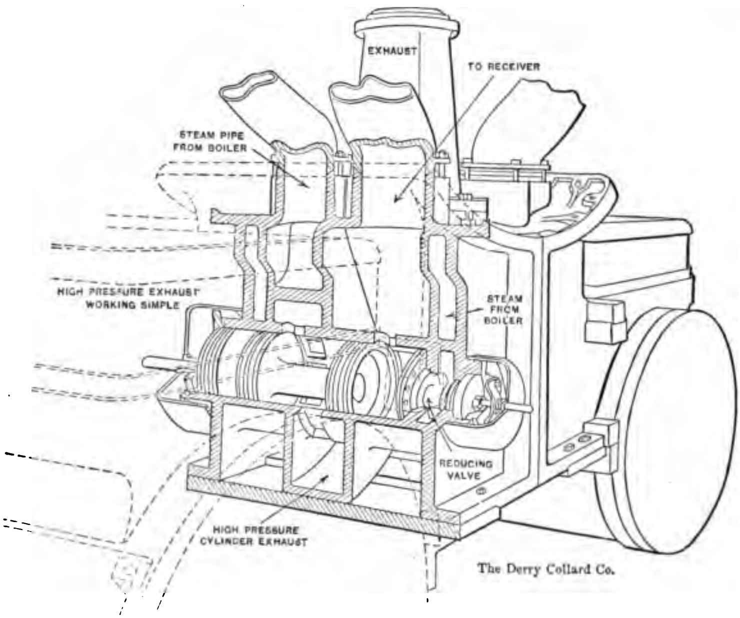


Figure 5. Pittsburg two-cylinder compound.
Intercepting valve in simple position.

doubtful improvement, however, and a good engineer beats any automatic device ever put out.

If one has followed the illustrations and traced the passage of steam in the other two-cylinder compounds, it is well to remember that in this case the intercepting valve is on the high pressure side, as before stated. This makes it seem different from the others, and it is well to bear this in mind when looking it over.

As will be seen from the drawing, the reducing valve is at the front of saddle and the intercepting valve at the rear, both being very simple and having no connection between them. There is a steam passage from the main steam pipe to the front of saddle and down into the reducing valve chamber between the heads of this valve. This supplies the low pressure cylinder with steam when working simple, as will be seen.

With the intercepting valve thrown into simple position, as shown in Fig. 5, the high pressure cylinder receives its steam in the usual manner and has a special exhaust opening between the heads of intercepting valve and out the exhaust port above, which happens to be just under the main steam pipe, as indicated.

In the meantime, the low pressure cylinder receives its steam through the reducing valve already mentioned, the steam flowing from this valve into the receiver and across to low pressure steam chest, where it is used same as in a simple engine, as is exhausted from the low pressure cylinder in the usual way.

Moving the intercepting valve into compound position, either by a special lever or by the reverse lever attachment, brings it into the position shown in Fig. 6. This has closed the passage from the reducing

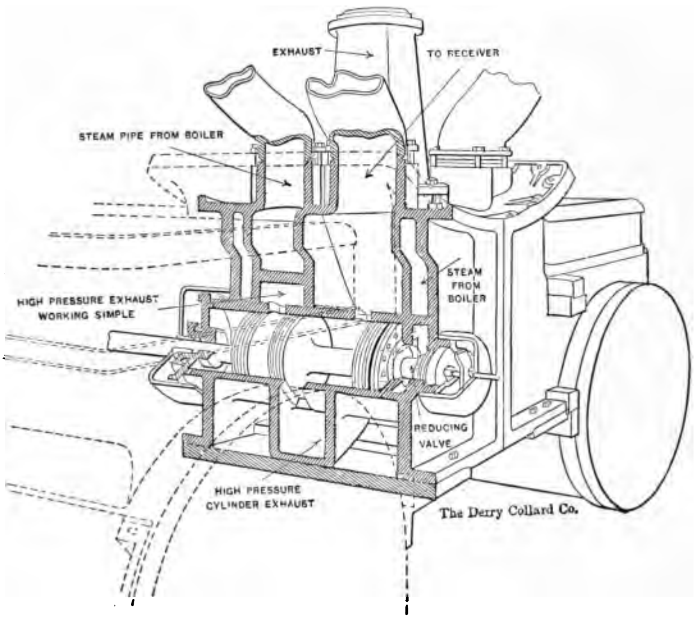


Figure 6. Pittsburg compound. Intercepting valve in compound position.

valve to the receiver and also the emergency exhaust of the high pressure cylinder, transferring it to the receiver instead. In this position the steam goes only to the high pressure cylinder, and the exhaust from the high must pass into the receiver and so supply the low pressure cylinder with steam.

A provision is made for switching and similar work where it is necessary to move the reverse lever very frequently, and is also desirable to use the engine in single expansion or simple position. This consists of a stop cock in steam pipe between boiler and reversing cylinder, and is within easy reach of the engineer. If this cock is closed when the reverse lever is in the first notch, the engine can be run simple as long as necessary, and at any point of cut-off.

It might appear from the drawing that the reducing valve was forced shut by the intercepting valve, in the compound position, but this is not the case. One does not come in contact with the other, but the reducing valve is closed by the accumulation of pressure on its outlet side when receiver is closed. This will hold it shut until the movement of intercepting valve into simple position allows this accumulation to escape into the receiver. Then the reducing valve begins to act as before, and the low pressure cylinder to receive its proper pressure of live steam.

The only particular inspection of this engine more than of a simple engine is in taking care that the drain valve at the back of the intercepting valve chamber is closed before starting out. As with any compound, it is advisable to work it as a simple engine for a few car lengths in starting a train before putting into compound position.

About breakdowns.

Breakdowns with this engine are easily handled, and in case of failure of either side, the intercepting valve should be placed in simple position, which means at the back end of the chamber in the saddle.

Should the break be in the high pressure side, there is nothing to do but block high pressure valve in the center the same as for a simple engine, and run with the low pressure cylinder. This would then receive its steam through the reducing valve, and the engine would act and run the same as a simple engine under the same conditions.

A break in the low pressure cylinder is even less trouble, for all that is necessary to be done is to prevent the low pressure cylinder receiving any steam. With the intercepting valve in simple position, this would come entirely from the reducing valve, so all that need be done is to take off front head of intercepting or reducing valve chamber and put a clamp of iron or wood in place of the spring. The reducing valve may then be screwed tight to its seat, and no steam can reach low pressure cylinder, so that the valve on that side need not be disturbed unless it is broken or some part of the valve gear, which will interfere with its movement.

The Pittsburg Works recommend the following method of handling this type of compound:

1. In starting, the reverse lever should be dropped down to the last notch from the center or full stroke. As soon as two or more revolutions of the drivers have been made, or train fairly started, move lever one or more notches toward center, when engine will be converted into compound.

2. When climbing grades, do not change engine from compound to simple if possible, and not unless

speed gets down to less than four miles per hour. Compound again as early as possible.

3. Engineers should take care to close the throttle to some extent just before changing from compound to simple, or the engine will slip badly on account of increased cylinder power.

4. Do not attempt to run engine notched higher up than 18 to 20 inch cut-off, even when running light; higher notching up only causes loss of steam by condensation in cylinders.

(This seems ill advised and unnecessary, as the quadrant should have no notches cut beyond the point where engine will work economically when working light).

5. The reverse lever should always be placed in last notch from center when engine is running with throttle shut off; if the engine is drifting down grade any distance, the throttle should be opened enough to show steam at cylinder cocks. (This is because no over-pass valve was provided on the engines at that time; it is probable that the Richmond or Schenectady over-pass valve will be used on any built by the American Locomotive Company, who control the patent).

6. The fire should be kept thin, but without holes; if engine does not steam well with thin fire, it should be reported to foreman or master mechanic, or whoever is in charge.

7. Set the lubricator to feed four times the amount of oil to the high pressure cylinder that it does to the low. As the exhaust from high goes to low when working compound, much of the oil fed to high goes over into the low pressure cylinder.

8. Oil the back end of intercepting valve at least

once a week, and the cup at front end should be filled each time engine goes out.

9. Remember that the sole office of the intercepting valve is to convert the engine from simple into compound, and back again into simple.

10. The duty of the reducing valve is to reduce the steam from the boiler pressure to a pressure in proportion with the areas of the high and low pressure cylinders. This is to equalize the work done by each cylinder when the engine is working simple.

11. It is necessary with engines compounded on this system to go into compound as soon as reverse lever is moved from full stroke, and should always go into simple position when reverse lever is put into full stroke notch either forward or backward. If this does not work exactly as it should, it must be reported at once and attended to. (This refers to the engines fitted with the automatic attachment to the reverse lever; the system can be worked simple in any notch without this attachment or when arranged for switching, as before stated).

Rhode Island Compound.

This was one of the first compounds to come into use into this country, and was built under the patents of the late Charles H. Batchellor, of Providence, R. I., dated September 22, 1891. Several of these engines went to the Brooklyn Elevated Railroad and some went to the West, but the works were idle during the panic of 1893 and so comparatively few of them were built. Later a number went to the Baltimore and Ohio and other roads, but the type is not very numerous at this writing. Still, it was one of the pioneers and deserves mention. The form of intercepting valve was changed somewhat by the later managers of the Rhode Island Works, and the form adopted by them is the only one shown, as the others are all out of service.

The intercepting valve was on the low pressure side, as with most designs, and is moved into compound by receiver pressure. The regular differential form of reducing valve is used and was first applied to the original Rhode Island compound, although this was the invention of Mr. Batchellor, after being shown the necessity of such a reducing valve by Henry F. Colvin.

There is a steam passage from boiler direct to low pressure side, and coming on top of the intercepting

Rhode Island Two-Cylinder Compound Locomotive.

valve as shown. There is also a hole drilled so as to give the steam a chance to force intercepting valve to the right or into simple position when starting a train.

As in the Richmond, Rogers and Schenectady types, there is a separate valve to control the high pressure exhaust. This is held closed by a spring, except when forced open by the steam or air from engineer's valve in the cab. In the simple position, as shown by Fig. 7, the intercepting valve receives live steam from the boiler, and passes it through the reducing valve by the ports shown. The separate exhaust valve is held open by steam from boiler (or air), and gives free exhaust for the high pressure cylinder through the auxiliary exhaust passages, E E. As long as the engineer considers it necessary to run the engine in simple position, he keeps his small starting valve open, and the high pressure has its own free exhaust.

Closing this valve allows the spring to close the high pressure exhaust ports, and the exhaust accumulates in the receiver until it forces the intercepting valve to the left and opens the passage to the low pressure cylinder. At the same time the live steam is cut out of the low pressure cylinder, as the ports are closed by the moving of the intercepting valve. The dash-pot at the left is provided to prevent slamming of intercepting valve, the same as in the Schenectady and Richmond types.

In case of breakdown the same general rules apply as to the other two-cylinder compounds, it being necessary to keep the steam out of broken cylinder in the easiest way possible, and to get the right amount in the low pressure cylinder if the high pressure side should be disabled. This means that in case of breakdown on

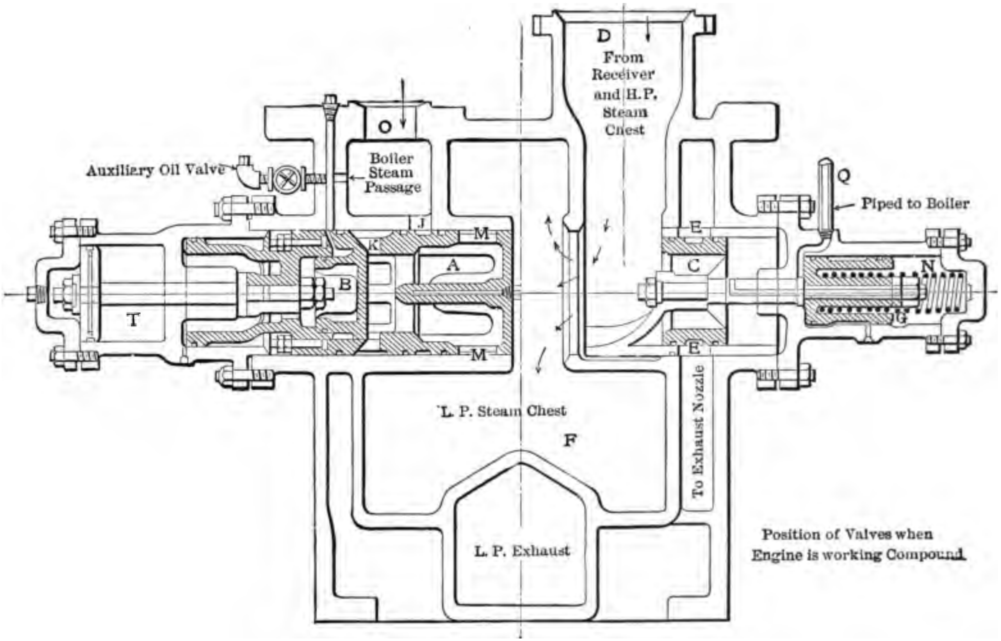


Figure 8. Rhode Island compound in compound position.

high pressure side, the steam from low must go through reducing valve to prevent excess pressure in that cylinder.

Putting intercepting valve in simple position will do this, and is the reason that in the majority of breakdowns the engine should be thrown into simple and treated just like a simple engine.

A break on low pressure side necessitates the valve on that side being blocked central over ports to prevent steam entering low pressure cylinder. Then engine is run with high pressure side, same as a simple engine

Richmond Compound.

This is sometimes known as the Mellin system, from the name of the patentee of a number of the devices used in its operation. In common with most of the others, it has the intercepting valve on low pressure side, to be moved by receiver pressure into compound.

The differential reducing valve is in the front end of intercepting valve chamber, and is plainly marked on cut. When starting in simple position, the live steam comes through a special port to this reducing valve and goes through this to the port marked "to low pressure cylinder." At the same time the high pressure exhaust comes over through the receiver, and finds an outlet at the emergency exhaust, which is held open by steam or air from the cab.

When the engineer changes his starting valve to compound, it shuts the steam out of the emergency exhaust and allows spring to close it. The exhaust from high pressure cylinder accumulates in the receiver until it is sufficient to force the intercepting valve to the right, which opens the exhaust port to the low pressure steam chest and closes the passage of steam through the reducing valve.

Starting a train.

Starting the engine with a light train the auxiliary exhaust for the high pressure cylinder is not usually opened, but the reducing valve is forced open by the live steam, and admits this steam to the low pressure cylinder.

The exhaust from the high pressure cylinder has no outlet, and accumulates in the receiver until it forces the intercepting valve to the right, opens the receiver to high pressure exhaust, and the engine then goes into compound automatically. The emergency or auxiliary exhaust will not open unless the engineer admits steam from the starting valve in cab, but the engine can be started as just described if train is not too heavy.

For heavy trains, however, the engine should be started as a simple engine and run in that position until train is under way (a few car lengths is sufficient), and then allowed to go into compound by shutting steam out of auxiliary exhaust valve.

Cylinder cocks should, of course, be opened when starting, to relieve condensation. This is very rapid in any engine during the first few revolutions, and when carried over from the high pressure into the low pressure cylinder, adds to the possibility of breaking out a cylinder head if the engine should slip in starting.

Starting a heavy train and when about to stall on a bad hill are the only times the emergency or auxiliary exhaust should be used.

Before starting, it is best to allow a few drops of oil to pass through right side of lubricator to the intercepting valve, but it should be shut off immediately when the engine is changed into compound. When

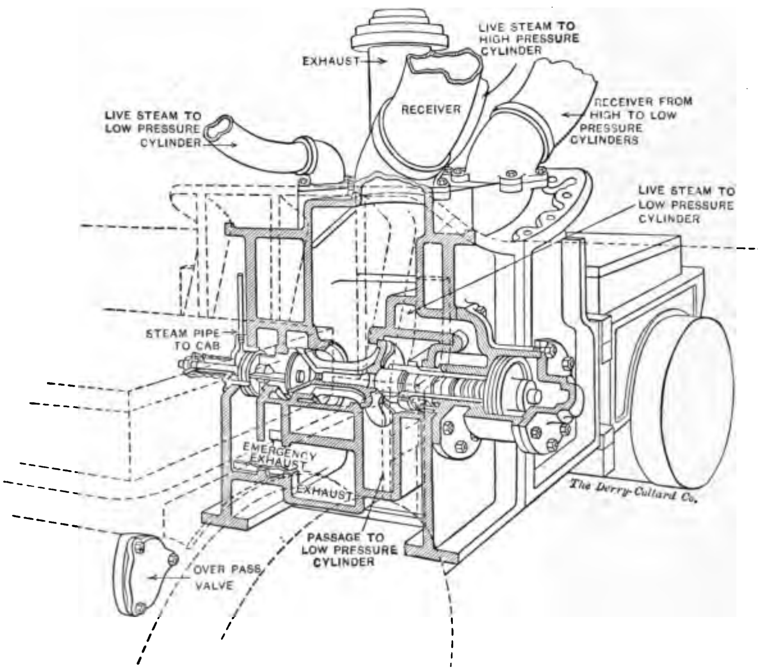


Figure 9. Richmond two-cylinder compound.
Intercepting valve in simple position.

starting in compound position, it is advisable to allow a small quantity, from 6 to 10 drops, to flow into low pressure side.

There is a small oil cup on the valve operating the emergency exhaust. This should be filled with cylinder oil every other day to lubricate this valve. Don't overdo it, however, and flood this valve. The amount named has been found sufficient.

Underneath cylinders will be found six small drip valves, screwed into steam and exhaust passages. These should have frequent attention, especially on new engines, as dirt and grit from new cylinders sometimes collect here and make them stick and leak.

Under the emergency valve is the exhaust relief valve, which is automatic. This opens when throttle is shut and allows air to pass to and from the cylinder when drifting, and prevents sparks being drawn into cylinder through exhaust pipe. It also modifies the action of blast on fire.

This should be examined occasionally, as when engine drifts with reverse lever hooked up too far sparks sometimes collect in this valve. The valve should, of course, be kept clean.

In this engine, or at least many of them, there is no oil pipe to the low pressure cylinder, but to the live steam passage of the intercepting valve instead. This plan lubricates the intercepting valve and low pressure cylinder when running simple, but allows no oil to go to the large cylinder when running compound except what is carried over with the steam from the high pressure cylinder. The builders recommend using as little oil as possible in the intercepting valve, on account of gumming up the small packing rings.

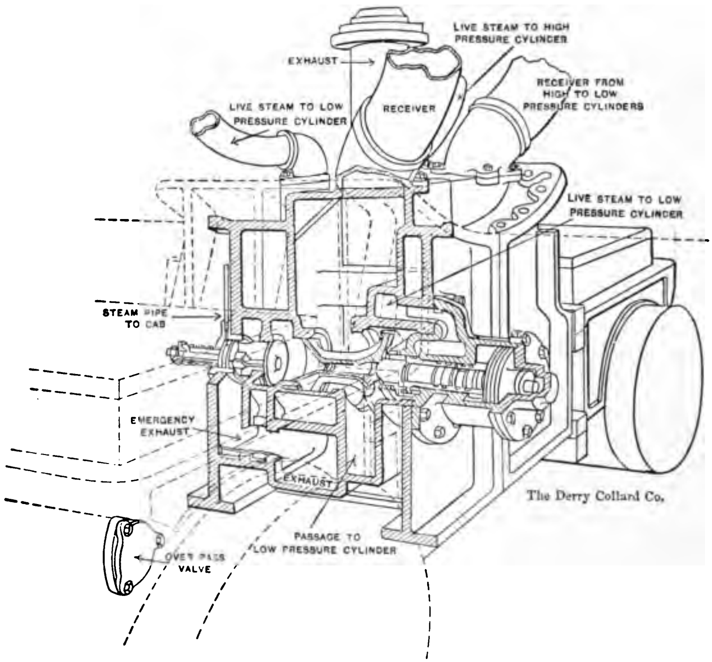


Figure 10. Richmond two-cylinder compound. Intercepting valve in compound position.

First over-pass valve.

The designers of this type of compound were the first to adopt the over-pass valve for relieving both compression and vacuum in the low pressure cylinder. This was first used on the Richmond "tramp," as the locomotive they used for demonstrating the value of their type of compound was called. It received this name from running on so many roads in different parts

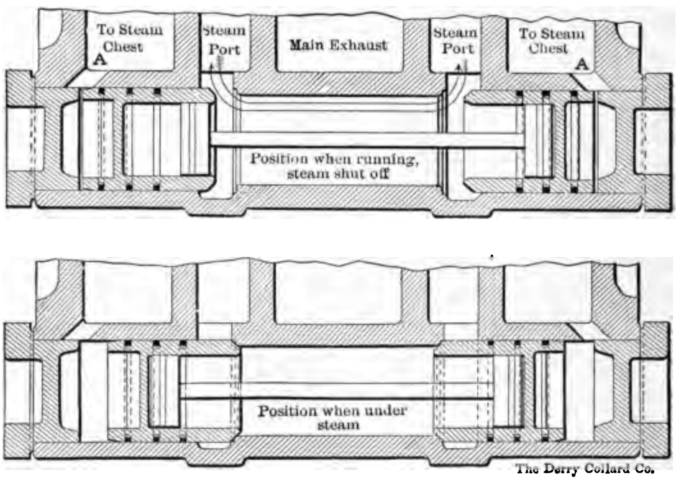


Figure 11. Drifting or over-pass valve of Richmond compound.

of the country. This is the locomotive shown in the plate of the Richmond compound. There is little doubt that this feature added to the efficiency of the engine, especially on hilly roads, for the reasons given in the section relating to over-pass valves. The illustrations show how the steam ports open to each other running shut off, and are closed when steam is in chest.

Rogers Compound.

The Rogers Locomotive Works have recently adopted the type of two-cylinder compound illustrated in Fig. 12, in which the intercepting valve is on the low pressure side, as is usual. Both the reducing and intercepting valves are in the casing S, which is fitted into a taper of 2 inches in 12, and is removable. Chamber B receives steam both from outlet D of regulating valve and from the high pressure steam chest through a number of connecting passages, Z.

The operating valve is practically a D valve, but has a round instead of flat face.

Live steam from cab regulating valve flows through E to chamber F and forces intercepting valve to right, closing exhaust valve Q. The high pressure exhaust comes into the center where shown, and forces valve J open at the right, allowing exhaust to go to stack. Live steam from B also flows down through passages H H to interior of intercepting valve, and after passing reducing valve R (of the usual differential type) goes to low pressure cylinder through receiver. The engine is now working simple.

After train is started, and the engineer wishes to throw the engine in compound, he moves regulating

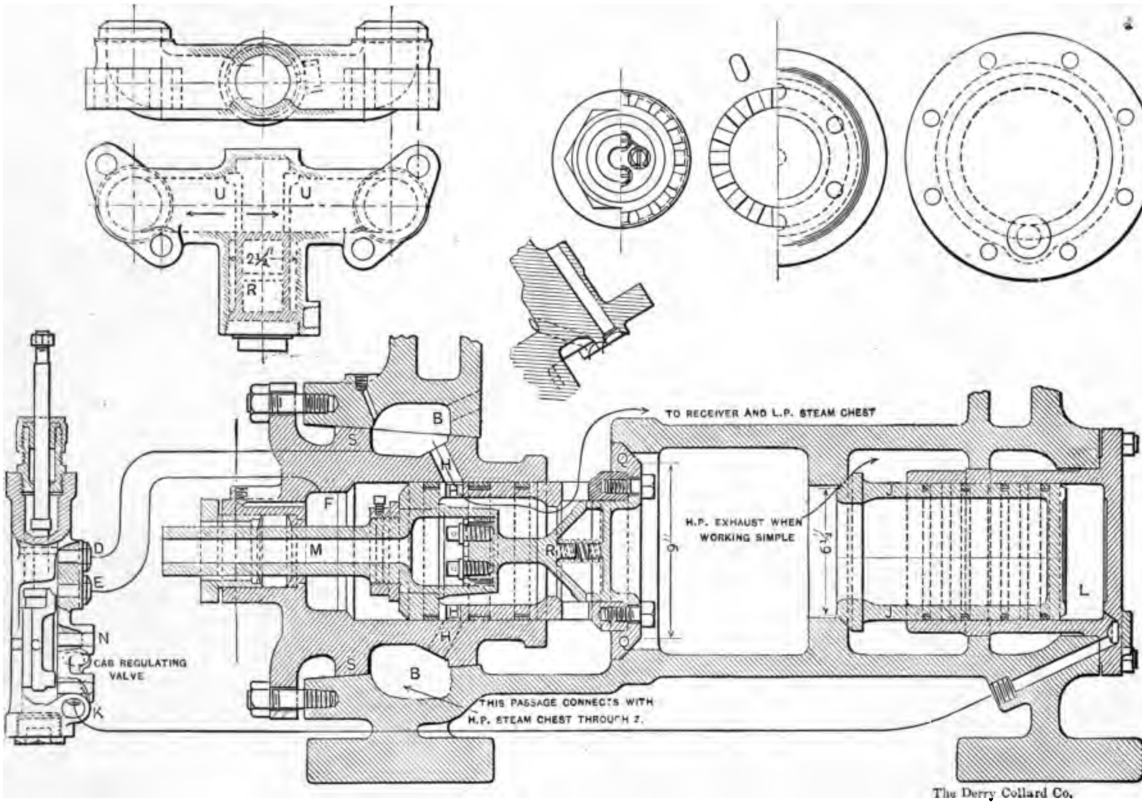


Figure 12. Starting valve, intercepting valve and by-pass valve of Rogers two-cylinder compound.

valve past E, putting chamber F into communication with the atmosphere through E, under valve C and out at N. This also opens K and admits live steam behind the valve J at L, forcing it shut.

The high pressure exhaust must now find another outlet, so it opens intercepting valve Q and goes to receiver and low pressure steam chest just as the live steam did before. Moving valve Q to the left closes ports H H so that no live steam can enter, and the engine is in compound. It will be noted that the small end of reducing valve is in a chamber which communicates through M to the atmosphere. This is to prevent any steam that might leak past the packing of small end of reducing valve accumulating a pressure and affecting its action. The section on reducing valves, page 100, will make this clear.

The over-pass valve is located just behind name plate of low pressure cylinder, connecting both ports by means of the passage shown in upper left hand corner of Fig. 12. When the engine is working steam, this passage is closed by the valve R being forced up into the center of U U. Opening V is piped to high pressure steam passage, so that live steam is always under valve when any steam is being used. As soon as steam is shut off, the valve R drops and leaves passage free. This valve, in common with all over-pass valves of this type, adds clearance to the low pressure cylinder. The area is also small, being only 3⅛ square inches for a 33-inch piston having an area of 855.3 square inches.

Schenectady Two-Cylinder Compound.

Closely following the Rhode Island engine came the first of the Schenectady two-cylinder compounds, also in 1890. These had no reducing valve, and went into compound automatically as soon as the receiver pressure accumulated to the running pressure. The advantages of independent control soon became apparent, however, and the new intercepting valve covered all the necessary points very thoroughly.

This has the combined intercepting and reducing valve and separate exhaust valve for running simple, which is under control of the engineer. The details can be clearly seen from the engravings showing the intercepting valve in both simple and compound position.

The independent or high pressure exhaust valve is normally held by the spring, and to run simple, it is necessary to admit steam or air (whichever way it is piped up) into the pipe C, which forces the exhaust valve to the left and gives the high pressure exhaust a free opening at A into stack. After leaving the high pressure cylinder, it goes over through the pipe marked "receiver" and out at A.

Schenectady Two-Cylinder Compound Locomotive.

Changing to compound.

The low pressure cylinder has a separate steam pipe as indicated, which admits boiler steam to the intercepting valve, and forces it to the right against the seat, opening a passage for live steam through the reducing valve and into low pressure steam chest. The reducing valve is of the same differential type which has become so universally used in engines of this class. These are explained on page 100.

To change to compound, the engineer shuts the steam or air out of the pipe C, and allows the spring to close the high pressure exhaust valve, cutting off the outlet for the exhaust from the high pressure cylinder. This then accumulates or banks up in the receiver, and forces the intercepting valve to the left, as indicated in the second engraving. This cuts the live steam out of the low pressure cylinder, and allows the high pressure exhaust to flow direct to the low pressure steam chest. It will be noted that there is a fair sized piston at the left and a small one inside the reducing valve; these are dash-pots, to prevent the intercepting valve being damaged by too sudden movement in either direction.

With a light train, it is sometimes unnecessary to start engine in simple position, and in that case the engineer does not admit steam or air to the pipe leading to high pressure exhaust, but starts the same as a simple engine.

Steam comes around intercepting valve and forces it to the right, so that the low pressure cylinder receives live steam through the reducing valve the same as before. There is, however, no exhaust opening for the high pressure cylinder, and it accumulates in the receiver until it is of sufficient pressure to force the intercepting valve to the left again, closing live steam open-

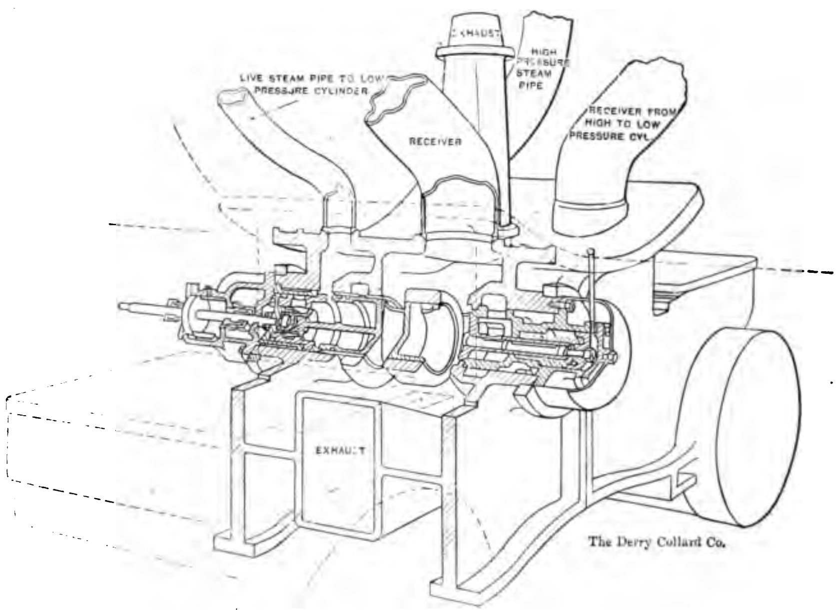


Figure 14. Schenectady two-cylinder compound.
Intercepting valve in compound position.

ing and giving high pressure exhaust a free passage to low pressure cylinder.

Engineers who have handled these compounds inspect the same as with a simple engine, except that they pay particular attention to the dash-pot, as the oil sometimes leaks past the packing and lets the intercepting valve move too fast. This might mean a slamming of the intercepting valve, and sometimes a break as well.

Starting is practically the same as other compounds of the two-cylinder type, the simple position being advised until the train gets under way and up to four to six miles an hour; then it should be thrown into compound. As with any compound locomotive, the fuel is not being saved when the engine is run simple. Starting the engine simple also gives a smoother start, and is less liable to break a train in two.

When running compound, some engineers put all the oil into the high pressure cylinder, keeping the low pressure oil pipe closed tight. The low pressure of steam in the large cylinder has a tendency to draw all the oil there and none goes into the high pressure cylinder. When put through the high first, most of it goes into the low with the exhaust, and so lubricates the cylinder on that side. When drifting, the low pressure cylinder needs more oil than the high pressure cylinder.

This compound, as well as compounds in general, should be worked at a longer cut-off than a simple engine, on account of having two cylinders to expand in. It is advisable to carry full boiler pressure at all times, or near as may be, and not to carry water any higher than to allow dry steam. The steam is expanded more than in a simple engine and often gets pretty damp by

the time the low pressure piston has reached the end of its stroke.

When coming to a hill, even if not a bad one, drop the reverse lever down a notch or two, and you can get up easier, without slowing down much. It is better to do this than to lose headway, as you may stall if you lose too much speed. If absolutely necessary, throw starting lever into simple position, and you will probably have no trouble. You must also get accustomed to the lighter draft of a compound, and have the engine fired accordingly.

Breakdowns are handled about the same as the other two-cylinder compounds. If high pressure side is disabled, steam must be got to low side. The best way is to block high pressure valve, so as to cover all ports, and let the low pressure cylinder get its steam through the reducing valve with the intercepting valve in simple position. Should the intercepting valve mechanism be disabled, the valve must be blocked in the simple position in some way.

Should the break be on the low pressure side, it is simply necessary to take care of the break and block valve, to cover ports, so it can get no steam. Open high pressure exhaust port either by steam or air, by blocking it open, and go ahead, as high pressure exhaust will then go direct to stack. This is one great advantage of an engine being made with a separate exhaust for high pressure cylinder. This was not done formerly, and is not now in some types in use in Europe.

If it is not possible to block high pressure exhaust port open, either from air pump failing or any other cause, block the low pressure valve clear back, so as to leave the exhaust port open, and then throw the en-

gine into compound. This passes the high pressure exhaust over through the receiver and into the exhaust port of low pressure cylinder, giving it a passage out of the stack, although not a very direct one.

A break in intercepting valve means running the engine simple after the valve has been blocked so as to allow this. This can usually be done by clamping the stem or rod, but if not, the head must come off and a block be inserted which will hold it in place.

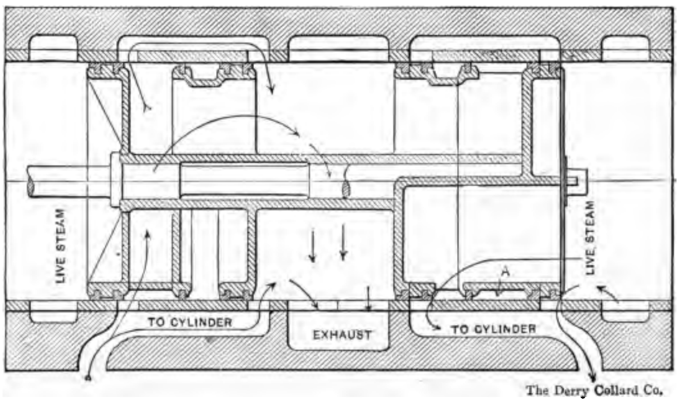


Figure 15. New low pressure valve, Schenectady two-cylinder compound.

The latest engines of this class have a double ported piston valve on the low pressure, as shown in Fig. 15. Its purpose is to provide double admission, the same as the Allen slide valve, and accomplishes this as indicated by the arrows. This design requires the use of ten packing rings, distributed as shown.

New low pressure valve.

Its design is somewhat difficult to understand from a drawing owing to the peculiar shaped passages for the steam.

In order to show this up clearly a modified engraving has been made with the passages indicated for the valve in that position.

Steam is being admitted at the right hand of valve and enters through the two ports shown, the center rings preventing its flowing to the exhaust through the annular passage, up around and into the central cavity and out of stack.

At the same time the exhaust from the other end is opened by the two paths shown. Here also the central packing rings separate the live and exhaust steam.

With the valve moving in the opposite direction, the other port openings in the valve come into play, which exactly reverses this, just as though this valve was turned end for end. It is difficult to show this in one drawing without making so many dotted lines as to be confusing. As will be seen, it has ten packing rings, and a leak is not easy to locate.

Vauclain Compound.

The Baldwin or Vauclain compound was patented in June, 1889, and is a four-cylinder engine, having one valve and one crosshead for each pair of cylinders; the cylinder ratios average nearly 1 to 3, and either the high or low is placed on top, according to design of engine. When fairly large wheels are used, the low pressure cylinder is usually placed at the bottom; on freight engines this is often reversed.

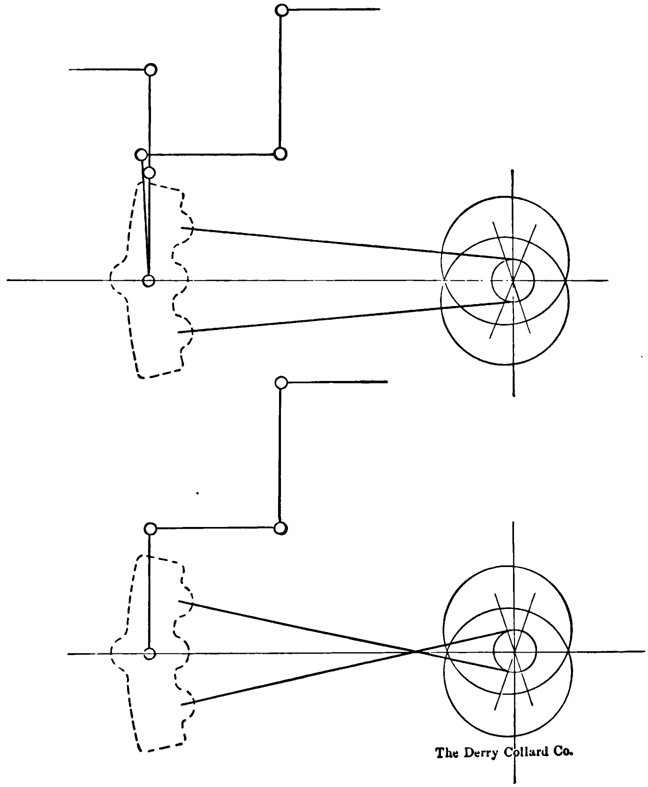
As will be seen from the illustration of the cylinders, they are cast together with the valve chamber and half saddle. A hard cast iron bushing is used in the valve chamber so as to give clean cut ports of the desired size, and to present a better wearing surface to the valve. This bushing is forced to place under pressure, which effectually prevents the passage of steam around the bushing or from one passage to the other, except under control of the valve.

The steam supply for the high pressure cylinder enters at each end of steam chest, so that the valve is in perfect balance, except for the slight difference in area due to the valve stem. This difference allows the steam to hold the two parts together in case the valve, or its connection to the rod breaks, as sometimes hap-

pens, and numerous instances are recorded where locomotives have pulled trains many miles in this manner with broken valves. The later engines, however, have the valve stem extended clear through the valve, and secured at each end. In some cases, also, the rod has been extended through the front end of steam chest to exactly balance the valve.

Cast iron packing rings are used in the valves, and it should be remembered that the rings are in reality the edges of the valve, as these control the admission and cut-off of the steam. This is of interest to the valve setter rather than the engineer. Different forms of rings are used, and some roads make a style of their own when replacing those broken in service. The bridges across the steam ports shown in the bushing prevent the rings from dropping into ports, as might be feared.

In some designs of engines of this type a "direct" valve motion is used—that is, no rocker arm is used—and the motion of eccentrics is not reversed, as in the regular engine. This generally occurs with engines having the low pressure cylinder on top, as the double front rail prevents the use of the usual rocker arm and box. An inspection of the eccentrics and valve motion will show this at a glance, and those looking after the valves should pay particular attention to it. With an indirect motion, the swell, or large part of the eccentric, is on the same side of the axle as the crank pin, while with the direct motion it is on the opposite side. With the crank pin on the forward center, the eccentric rods should be crossed, if it is a direct motion. The illustrations, Figs. 16 and 17, show this, so that no mistake may be made.



Figures 16 and 17. Direct and indirect valve motion,
with and without rocker arm.

Starting a train.

In addition to the usual air valves on the main steam passage to high pressure cylinder, there are valves on the passage leading to low pressure chest to prevent the formation of a vacuum and the drawing in of cinders, with their attendant damage. Relief valves are also applied to front and back heads to save cylinders from rupture in case of working water and to relieve excess pressure from any cause whatever. These are the main points of difference from the ordinary simple engine. The action of the steam in the valve and cylinders can be seen by referring to sectional cut, Fig. 18, and is as follows:

Steam comes from boiler to both passages marked "inlet," and with the valve as shown, the right hand or front port is open and admits the steam from the inlet to the "high pressure passage." At the same time the other end of the high pressure cylinder must be exhausting, and the "high pressure" passage at the left is shown open, communicating with the center of the valve.

Flowing through this the steam passes into "low pressure" port or passage and goes to the low pressure cylinder. As this cylinder must also be exhausting, we find the "low pressure" passage at other end open to the center port, which is the exhaust and leads to the stack. The action will be seen to resemble very closely that of two D slide valves moving together.

In starting with a train, live steam is admitted to low pressure cylinder by opening by-pass valve from the cab. This allows live steam to pass from one high pressure passage to the other, which, in the case shown, would pass live steam direct to the front side of the low pressure piston. The by-pass pipe, being small, pre-

vents the low getting full boiler pressure, unless the engine starts so slowly that it has time to accumulate behind the piston. This pipe also allows the pressure

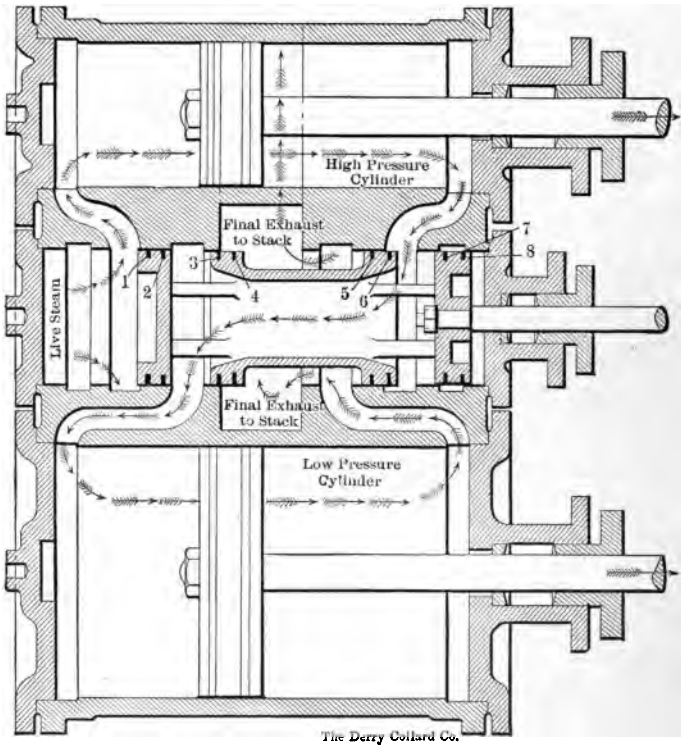


Figure 18. Cylinders and valve of Baldwin or Vauclain four-cylinder compound.

to equalize on both sides of the high pressure piston, so that in starting the low pressure cylinder is doing all the work.

This by-pass valve also acts as a cylinder cock for the high pressure cylinder. It should be used as little as possible, as, when open, it reduces the economy and tends to make the engine logy, or not "smart," as all engineers like a locomotive to be.

As the result of over ten years' experience with these engines, the Baldwin Locomotive Works make the following suggestions in regard to running their four-cylinder Vauclain type:

Learn to use the reverse lever more than you may have done on simple engines, and if there is a tendency to slow down on a hill, throw the lever forward at once. The reverse quadrant has no notches for cut-off under half stroke. This avoids damage that might occur from excessive compression.

The engine can be run with reverse lever in any position between half and full stroke without serious damage to fire, as the expansion of the steam, due to the difference in cylinder volume, when working full stroke, is about the same as a simple engine cutting off at ⅓ stroke.

Where possible always open cylinder cocks on starting, to relieve cylinders of condensation. The starting valve and cylinder cocks being attached to same lever, the same movement on the part of the engineer admits live steam to low pressure cylinder. This starts the train easily and quickly. There are cases, such as in a crowded station, where cylinder cocks can not be opened, and in this case the by-pass only should be opened so as to start train. As soon as the water from both cylinders has worked through the low pressure cylinder, the by-pass should be closed and the engine worked compound. This should be

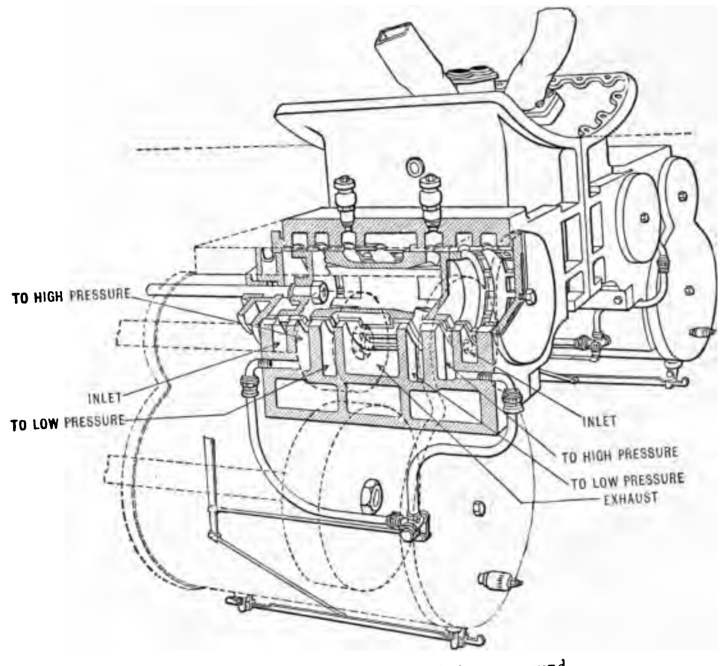


Figure 19. Vauclain four-cylinder compound.

done before the reverse lever is moved from the full stroke position. It should never be hooked up (thereby shortening valve travel) with the by-pass open.

If it becomes necessary to relieve the cylinders of water when at high speed, due to carrying the water level a little high, the cylinder cocks can be opened without disturbing the reverse lever, and then closed as soon as the engine is working free.

Remember that the economy of a compound depends largely on its greater range of expansion, and that to secure this the reverse lever must be used intelligently. As the speed of the train increases after the starting valve has been closed, the reverse lever can be hooked up gradually until the maximum power of the engine is obtained. If this is more than you need, throttle as much as necessary.

Throttle very close on slight down grades, only using steam enough to keep air valves closed. On steeper grades close throttle, and move reverse lever gradually forward to full gear notch, then move starting valve lever full back. This allows the air to circulate either way through starting valve from one side of piston to the other, relieving the vacuum, and prevents blowing the oil out of the cylinders.

On heavy grades, or with heavy trains on any grade, do not allow the speed to decrease materially, but move the reverse lever forward enough to maintain good headway. If the speed still drops and there is danger of stalling, after lever is in full forward notch, use starting valve to admit steam to low pressure cylinder. This is only for emergencies, and should not be done longer than necessary.

The starting device should not be used except in

actual "starting," and should be cut out as soon as train is in motion (except in emergency stated above). Cases have been found where it was used all of the time, with the result of burning an excessive amount of coal for the work done and slowing down the speed of the engine.

The mild exhaust enables the fireman to carry a lighter fire than in a simple engine; this should be as light as possible. Practice and care will soon show him how to do the work with the least amount of fuel.

The water used per horse-power hour varies much less than in a simple engine when the reverse lever is moved towards full gear or longer cut-off. This makes it possible to move the reverse lever of the compound into any desired position without fear of increasing the water consumption as in the simple engine, and live steam should not be admitted to the low pressure cylinder until the last notch of the quadrant has been tried, and the engine is about to stall.

In case of broken high pressure cylinder head, block valve on that side in central position, so as to cover ports; disconnect main rod and block crosshead same as with simple engine. Run in with other side, working compound if possible; simple, if necessary, as it probably will be. Should both high pressure cylinder heads break, the engine is out of commission, unless you can block high pressure ports, which is practically out of the question.

Breakage of high pressure piston rods or piston heads means the removal of broken piston and rod and the plugging of piston rod hole in cylinder head from the inside with wooden plugs. Then replace head or heads, and run in light.

Broken cylinders and pistons.

Low pressure cylinder heads and cylinders are most apt to break. When this occurs, run with starting valve in compound. This practically gives a simple engine of the dimensions of the high pressure cylinders. The exhaust from the high pressure goes through low pressure cylinder and to stack. With a serious break, the blast on fire might be so reduced as to prevent steaming.

When low pressure piston heads let go, as they sometimes do, remove piston and rod, and plug piston rod hole same as with high pressure cylinder. Run light with starting valve in compound.

Although it may seem somewhat strange, it is not always easy to tell when the low pressure piston head is broken, and there are numerous cases where the engine has been run for several days without detecting it. The only difference noticed was that the exhausts were not square and the engine was weaker than usual. If an engine comes in with these symptoms, it is safer to look at the low pressure piston before altering the valve motion.

Tandem Compounds.

Although the first American compound locomotive was of the tandem type (Perry & Lay, see page 8 this volume), the two-cylinder (cross-compound) and the Vauclain four-cylinder type are much more commonly used.

The Brooks Works put out a tandem in 1892, but the design was complicated (especially the valve connections) and it did not meet with favor, particularly as there was no difficulty at that time in building two-cylinder compounds as powerful as was demanded.

The increased demand for larger locomotives brought out two-cylinder compounds with low pressure cylinders as large as 35 inches. Most designers claim that this is the limit, as the engine width cannot be kept within the limit if it is exceeded. One designer, however, has plans for using a 37-inch low pressure cylinder, and many think that is large enough for any engine.

The first of the tandems, excepting the Brooks, already mentioned, was built by the Schenectady Works in August, 1900, for the Northern Pacific, and its success led to recommending that type for large

locomotives. Since then many have been built, and the different designs are shown in this section.

Assuming that four cylinders are necessary to do the work, the choice lies between the Vauclain type, with both cylinders on each side connected to one crosshead, the tandem, and the balanced or inside crank engine.

The Vauclain design is best known because it was one of the first, and has been most vigorously pushed by the Baldwin Locomotive Works, several thousand having been sold at this writing.

It has but one crosshead, same as the tandems, but this is subject to tremendous strains, owing to the unequal power in each cylinder, which is unavoidable. This has been recognized by the designer, and the crosshead and guides now used are made heavy enough to stand this strain. Some claim that a slide valve would give better results than the piston valve used, and others that a valve for each cylinder would greatly improve the engines. As the builders know of these criticisms and suggestions, they evidently feel that they are not well founded, or they would doubtless adopt them.

The tandem type of compound puts the cylinders in line, and all the strains as well. There is one piston rod, one set of guides and one connecting rod, but all use a valve for each cylinder, although both are driven by one valve rod. Most of these are piston valves. A few use the regular D slide valve, or a modification of it. The unequal strains on the crosshead of the Vauclain type are done away with, but in most of the designs the method of examining pistons is unnecessarily complicated and takes altogether too much time.

Baldwin Tandem.

The first of these was built for the Atchison, Topeka and Santa Fe Railroad in the spring of 1902, and was the largest and most powerful engine built up to that time. It weighed 267,800 pounds, had cylinders 19 and 32 inches by 32-inch stroke, 5,390 square feet of heating service, and a drawbar pull of 62,500 pounds. The cylinders are inclined one inch in 24. The sectional view shows the connection between the two, as well as the valve in position.

The ports in the high pressure cylinder are not crossed, as in the Schenectady.

There is a sleeve between the two steam chests which is packed by a gland, so that the joint can be readily broken and replaced without difficulty.

It will also be noted that the high pressure back head and low pressure front head are fastened together by small studs, and that both are clamped between the cylinders by the bolts shown. This is a rather novel and unusual arrangement.

A small crane is fastened to each side of the smoke arch, and a ring in the top of high pressure cylinder enables it to be swung out of the way, if care is taken to

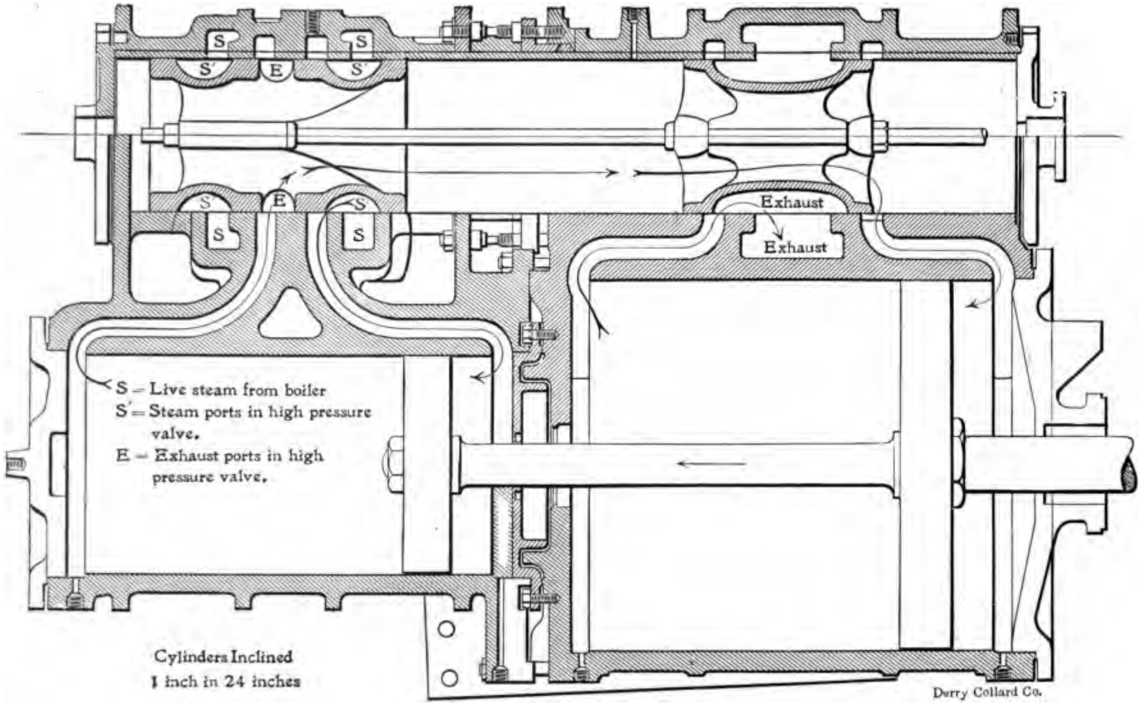


Figure 20. Cylinders of Baldwin tandem compound.

have that side of the engine on the back center. Then by removing piston rod key, the whole rod, with both pistons and the intermediate cylinder heads, may be removed for examination.

The action of the steam can be readily followed from the sectional view. Steam comes from boiler to ports S S. As will be seen, there are two annular steam ports, S′, S′, S′, S′, in the high pressure valve, which in the position shown is admitting steam to the back end of the high pressure cylinder, as indicated by the arrow. At the same time the exhaust from this cylinder passes up through the central port into the center of hollow valve and through the sleeve surrounding the valve rods, and connecting the two steam chests to the low pressure steam chest.

With valve in position shown, it must pass through low pressure valve, which is also hollow, and enters low pressure cylinder through back port, as shown, so as to force low pressure piston in the same direction as the other. As any repair work is the same as a simple engine, except that there are two cylinders on a side, no special directions are needed. The exhaust from the low pressure cylinder goes out around center of valve to the stack.

Damage to either cylinder requires that some means be found to keep steam out of that while allowing it to do its work in the other. The easiest way is generally to block both cylinders of the damaged side by clamping the valve central over the ports and to run home on one side.

The by-pass arrangement is very simple. As with the others of this type, it is only necessary to have a free passage between the steam ports of the high pres-

Baldwin Tandem Compound Locomotive.

The Colvin-Wightman Tandem

One of this type was built by the Pittsburg Locomotive Works just previous to their entering the American Locomotive Company, and went to the Baltimore and Ohio Railroad. It met with opposition, as was to be expected, but it was soon learned that the "1705" could be depended on, and it proved very satisfactory. In the general changing of compounds into single engines on that road, however, it was allowed to run without attention until general repairs were necessary, when it was also changed to a simple engine, along with 256 Vauclain compounds.

The engine possesses some novel features, however, and as it is likely to be built by other parties, they are shown herewith.

It differs from the other tandems in having quite a space between the high and low pressure cylinders. This allows a very neat arrangement of examining pistons without taking off cylinders or guides, as is necessary in some designs.

The sleeve between the cylinders is bolted to the low pressure head, but fits inside the high pressure head, the joint being made by a metal gasket, held in place by the ring shown.

Colvin-Wightman Tandem Compound Locomotive.

Examining pistons.

If it is desirable to examine piston, the front head of the high pressure cylinder and the nuts on the front low pressure head are removed, and the gasket packing ring loosed. Then, by taking piston rod out of crosshead, the whole rod is moved forward until both pistons are visible. The sleeve simply pushes into the high pressure cylinder and does not have to be removed or the packing interfered with. This tandem has slide valves and no crossed ports. The section cut shows the engine in simple or "starting" position, the by-pass valve being moved so as to allow live steam to pass down through the vertical port and to the low pressure steam chest through the connecting pipe between the two chests.

Steam also passes down through high pressure balance plate through the ports in high pressure valve and into cylinder. The exhaust is in center of high pressure valve, and this exhaust cavity opens at each end into the exhaust steam chest, as shown in Fig. 3. As live steam also enters this space through port left open by the by-pass valve, the steam on each side of high pressure piston balances, and this does no work in starting position.

The live steam, however, passes to low pressure chest and acts on the large piston at full boiler pressure, which is all the engine should stand, and starts the train.

The by-pass valve has holes through it, as shown in Fig. 22, and admits steam through it in either position. When it is turned into vertical position, the vertical port is closed, and live steam can only go to high pressure steam chest. The engine must then work compound. In this position the live steam

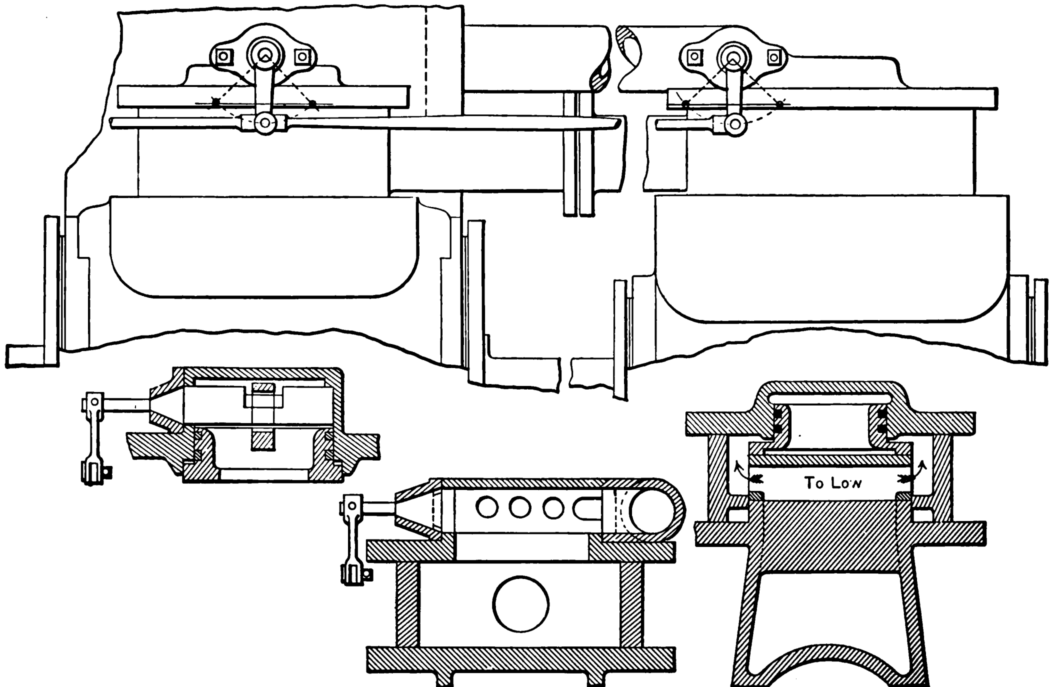


Figure 22. Details of by-pass or drifting valve of the Colvin-Wightman compound.
High pressure exhaust to low is shown.

enters high pressure cylinder through port shown, and exhausts through center of valve and out the ends into exhaust chest, as before shown. This goes to low pressure steam chest, is admitted to low pressure cylinder by the outside of the valve, while the exhaust goes out through center of this valve through balance plate and to exhaust nozzles and stack.

Slide valves and balance plates of this kind are not found elsewhere in locomotive practice.

The method of relieving vacuum, compression, and the other evils of drifting, is novel, and practical use has demonstrated that it was effective. The cam shown in sectional view of low pressure balance plate has no effect in either simple or compound position of the lever controlling by-pass valve. When drifting with steam shut off, however, this lever is moved to its extreme position when the right hand corner of cam lifts the balance plate away from valve and allows it to lift just as a plain slide valve does. This gives the entire area of the low pressure ports for relieving the compression, and the engineers who have run it say it drifts like a box-car. It will be noted that this large relief area is obtained without adding a particle of clearance to the cylinder—a point that is well worthy of consideration, as clearance and economy are closely related.

Blows of pistons and valves would be handled as described in the section on that subject, and breakdowns need little further explanation. It is necessary to keep steam out of disabled cylinders in the quickest way possible, and after understanding the description of the engine, this should not be difficult in any case.

Schenectady Tandem.

The arrangement of cylinders, pistons and valves, and their relative positions, is shown in Fig. 23, in which the high pressure cylinder is ahead of the low pressure cylinder, both pistons on the same rod, and the steam chest common to both cylinders. The piston valves of both cylinders are open from end to end, and the space between and around them and inside the steam chest serves as the receiver.

There being no receiver except as above mentioned, the smoke-box or front end is fitted up with steam and exhaust pipe exactly the same as in the case of single expansion engines.

The high pressure cylinders have internal admission valves, while those in the low pressure cylinders are of the external admission type. This allows steam to be admitted to the same side of each piston at the same time, by means of the crossed ports on the high pressure cylinder.

To work the engine simple or compound at will, a starting valve is fastened to the side of steam chest over the high pressure cylinder, and having direct communication with the steam passages into that cylinder. This casing also contains the by-pass valves for the high pressure cylinders, both being worked together.

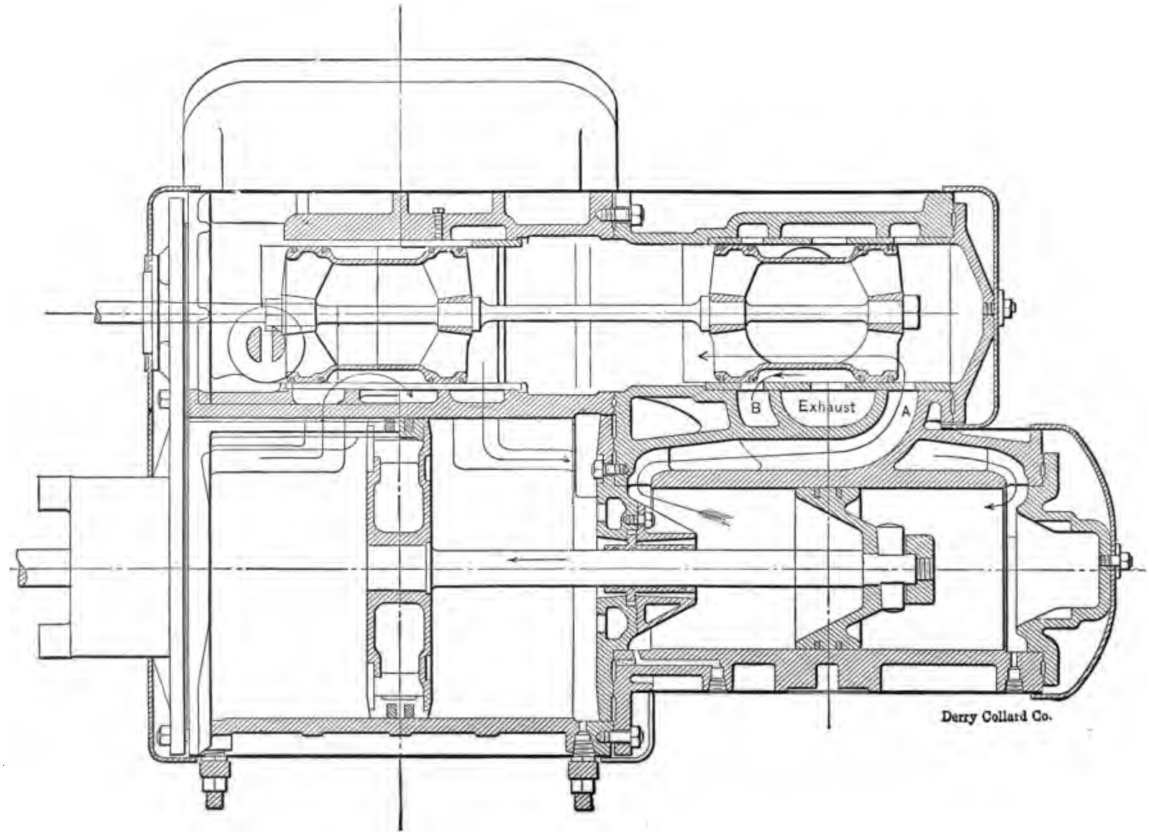


Figure 23. Cylinders of Schenectady tandem compound.

Schenectady tandem by-pass.

For relieving the low pressure cylinder of excessive pressure when working steam, or freeing it from back pressure when drifting, the by-pass valves shown in Fig. 24 are used. These are bolted to the side of the steam chest near each end of low pressure cylinder, and furnish communication between the steam chest and the steam ports in cylinder. Excessive pressure raises valve and relieves it into receiver as indicated. The engraving gives the details and main dimensions. There is also a relief valve on back head of steam chest, to relieve from excessive pressure.

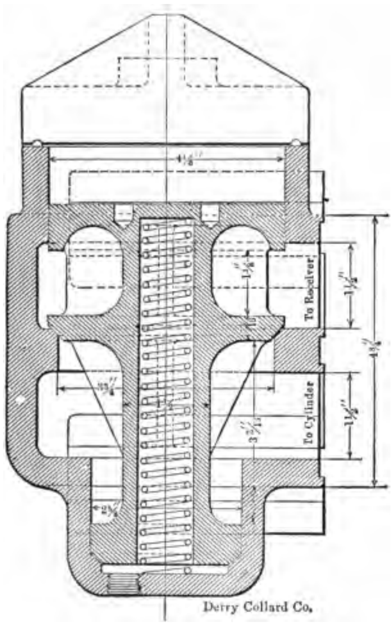


Figure 24. By-pass or drifting valve of Schenectady tandem compound.

In starting the locomotive as a simple engine, steam is admitted directly to the low pressure cylinders, by placing the starting valve A in position shown on Fig. 25. This is done by means of a lever in the cab connecting with the end of starting valve spindle. Steam is admitted to high pressure steam chest through the short steam pipe connecting saddle and chest, and passes through ports D and H, which register with pressure

steam ports in steam chest. From D the steam is admitted to ports E and G, and passes around the by-pass valves B B, reaching port H. The valves B B are held up to their seats by pressure from below through port C, which opens directly into the steam chamber of chest. Steam, having access to both high pressure steam ports, passes through both hollow piston valves, and is admitted to the low pressure cylinder, the locomotive now working as a simple engine. The high pressure pistons have steam on both sides at this time, and the forces are balanced; all work, therefore, is done by the low pressure pistons.

To throw into compound, the starting valve A on Fig. 25 is brought to lap on port E, shutting off high pressure steam from its passage into the low pressure end of steam chest. Under these conditions no steam, except from the exhaust of the high pressure cylinder, can reach the low pressure cylinder.

When drifting or not working steam, the by-pass valves B B, in Fig. 24, being in a vertical position, fall clear of their seats by gravity, and give a clear opening between the two ends of the high pressure cylinder, and any accumulation of pressure in that cylinder is relieved by passing through the steam chest to the relief valve, on rear head of steam chest. The by-pass valves for the low pressure cylinders are held to their seats when working steam, and operate to relieve excessive pressure by raising when cylinder pressure is greater than steam chest pressure, allowing the excess to pass from the cylinder by way of bottom port, which opens into cylinder steam port, thence through top port opening into steam chest, and from there out of relief valve. When running with closed

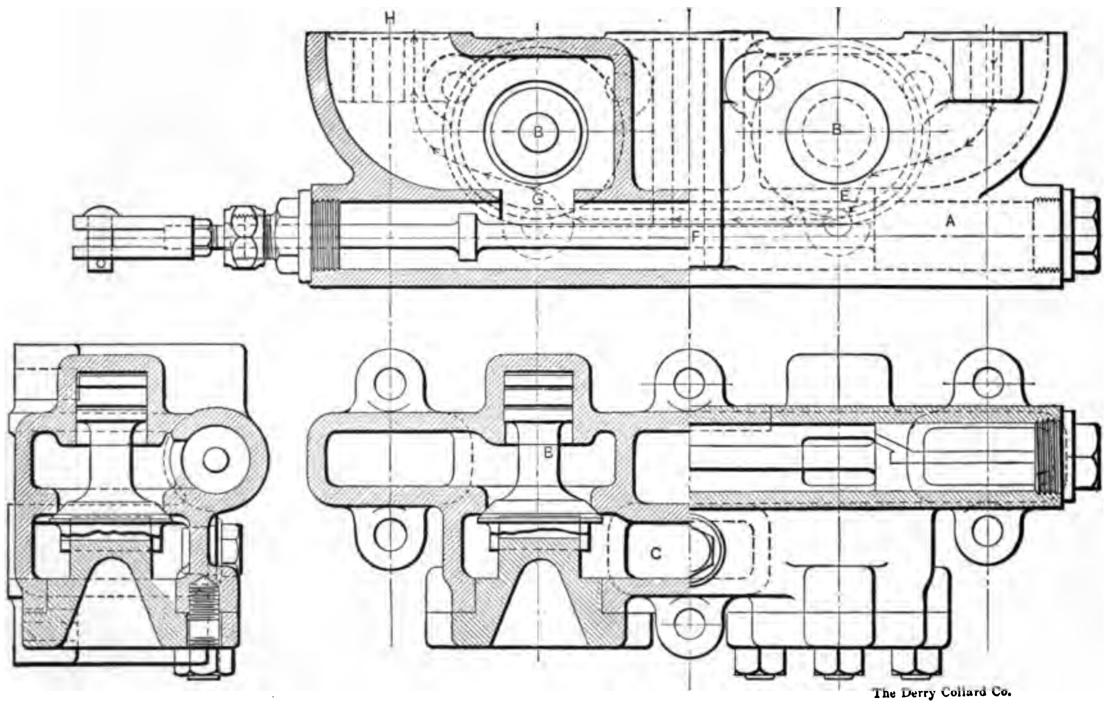


Figure 25. Starting and over-pass valves of Schenectady tandem.

throttle, the by-pass valves are raised from their seats by the spring under valve, assisted by the absence of pressure on top. With the valves raised from their seats, there is a clear opening between the two ends of low pressure cylinder, through cylinder steam ports into steam chest, providing relief from back pressure when drifting, by equalizing the pressure in both ends of the cylinders.

Any compound engine will do more economical and satisfactory work operated as a compound, and should, therefore, never be worked as a simple engine except in starting, or when likely to stall on grades, and then only long enough to overcome the resistance of the train. The engine should never be worked simple when it can be avoided.

Attention should be given to the quantity of water carried in the boiler, with the view of using steam as dry as possible. Water should not be any higher than will insure dry steam, since wet steam is not conducive to economy in operation, and is also a menace to proper lubrication. It is always an element of danger with piston valves, even when provided with by-pass valves.

When running under steam, the high pressure cylinder should receive the greatest amount of oil. When drifting, the reverse should be the rule, the low pressure cylinder having the most oil.

When necessary to disconnect the engine on the road, on account of accident, the same methods may be used as in case of a simple engine as to removal of parts and blocking of crosshead, etc. This refers to proceeding with one side, when the trouble is located with the valves or pistons, since each side constitutes an engine in itself the same as a simple engine.

Balanced Locomotives.

The balanced type is ideal in many ways. It is not new to this country, being a modification of the much ridiculed "Shaw" locomotive. Probably the first of this exact type in this country was George Strong's balanced compound, which was tested at Purdue University in 1898.

The French have been using this class on some of their fast trains for some time, where it is known as the DeGlehn type. Baldwin built the first in 1902 for the Plant System, but it was sold to a Chicago railroad instead.

There is no doubt as to an engine of this kind being balanced and the effect of the counterbalance being done away with. The question to be solved is, "whether or not the remedy is more expensive than the disease."

If the ordinary type of locomotive can not be balanced so that its injuries to rails, roadway and bridges is less expensive than the extra cost of engines of this class, the "balanced" type has come to stay, but the introduction will be slow in any case, as most motive power men hesitate to add a radically different class of locomotive to their already too numerous list of classifications.

Baldwin Balanced Compound.

The different views make the peculiar features of this engine very plain, the front view showing location of high pressure cylinders under the center of the smoke arch and between the frames, the low pressure cylinders outside and the piston valve above and between the two. It will be noted that the valve in this case is the same size as the high pressure cylinders.

As in the Vauclain type of four-cylinder compound, there is but one valve to control the steam for both cylinders, though of different construction. In fact, this may be likened to a regular Vauclain engine, with the cylinders side by side, rather than one over the other. The only difference is that in the other the pistons move together, while in this case they move in opposite directions. This is what necessitates a different valve from the regular Vauclain engine.

The main dimensions are given, so that the distance required between cylinders and between valves and cylinders, as well as the frames and height of saddle, can be seen.

The patent office drawing of this engine showed a rather peculiar connection, in which the inside or high pressure cylinders were connected by cranked axle to

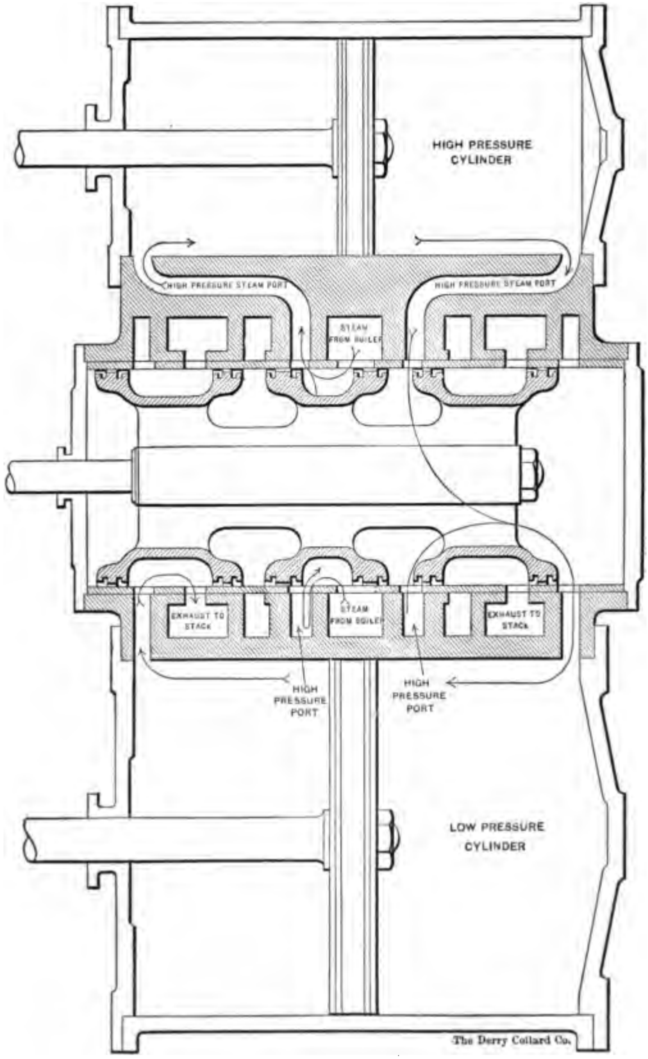


Figure 26. Cylinders and valve of Baldwin balanced engine, DeGlehn type.

forward drivers and the outside or low pressure cylinders to the second pair. This would have made a very short main rod for the high pressure cylinders and long rods for the low pressure cylinders.

This was not carried out, however, and the first engine of this type had both inside and outside connections on the forward wheels.

In order to show the valve movement and the action of the steam, a special engraving has been made, in which the valve is shown directly between the cylinders, as was done in the case of the regular Vauclain type of compound. This makes the action clearer and gives the correct idea better than an exact reproduction would do.

Although both pistons are shown in the center of their stroke, they are moving in opposite directions, as will be seen from the arrows indicating the flow of steam.

Steam from boiler comes in at the central port, which is so marked. Flowing around the central portion of the valve, it goes in to high pressure steam port as shown, and forces high pressure piston to the right.

At the same time, the exhaust from the high pressure cylinder is flowing out from the other side of the piston through the other port and out through the opening in the valve, shown by arrows. From here it goes to the right hand end of low pressure cylinder, as shown, being controlled by the outside edge of the valve. This drives the low pressure cylinder in the opposite direction from that of the high.

The exhaust from the low pressure cylinder goes out of opposite port, under the end cavity of valve and

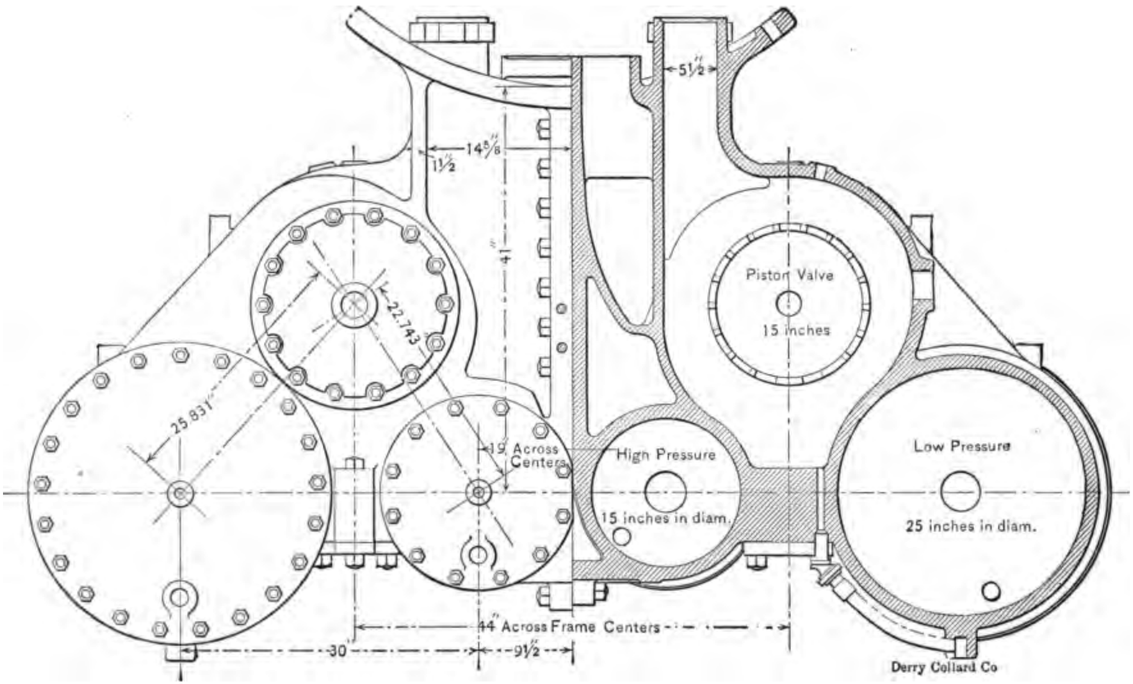


Figure 27. Cylinders and saddle of Baldwin balanced engine, DeGlehn type.

to the stack. As will be seen, it is simply a modification of the regular Vauclain valve, the different conditions of the pistons moving in opposite directions, necessitating the change and the addition of four packing rings, making twelve in all.

The central portion, with its four rings, may be called the high pressure valve, having inside admission, while the ends are the low pressure valves, one for each end of the cylinder.

Each cylinder has its own crosshead and guides, those for the high pressure cylinders being between the frames and those for the low pressure cylinders in the usual place. The repairs of these are exactly similar to those used on simple engines.

The high pressure cylinders are inside connected or connected to a cranked axle. Should it be necessary to disconnect, it will not be difficult to do, as the manner of taking down will be made plain to any mechanic.

The valves, being so high above the center of the cylinders, are driven by indirect motion in usual way, a rocker being employed to reverse the motion.

The valve, being inside admission, must move in an opposite direction from the usual D valve, with outside admission. This means that the swell part of the eccentrics must be away from the crank pin if a rocker arm is used, or toward it if it is a direct motion. As the valve is considerably above the cylinders or line of motion, the rocker is used.

The balanced compound requires a by-pass for the high pressure cylinder the same as the tandem. This is necessary, in order to use live steam in the low pressure cylinders, in starting a train or to prevent stalling on a heavy grade.

Baldwin Balanced Compound Locomotive.

Plans for Balancing.

Following the idea of Frazer Selby, as previously mentioned, Mr. F. W. Johnstone, of the Mexican Central Railway, designed in 1892 some double-ended compounds having high pressure cylinders inside of the low pressure cylinders.

This was not the only peculiar feature, and as there is a tendency on the part of some more recent designs to follow this practice, some of the details of this engine will be shown. It requires several illustrations to show the connections clearly, and the only excuse for giving it so much space is the hope that it may deter others from making a similar failure.

As will be seen, the high pressure cylinder (there were four of them) was 13 inches in diameter, while the low pressure was a ring 16¾ inches inside and 28 inches outside.

The three rods connected to one crosshead, so that both pistons moved together. The crosshead was connected to lever A, which drove the main crank pin through the lower main rod, shown in the complete picture. This connected at the top with lever B through the link shown, and the inside of this lever was fastened to the frame at C. The lower end of B connected with the auxiliary crank pin, shown at the top at D, in Figs. 29 and 30.

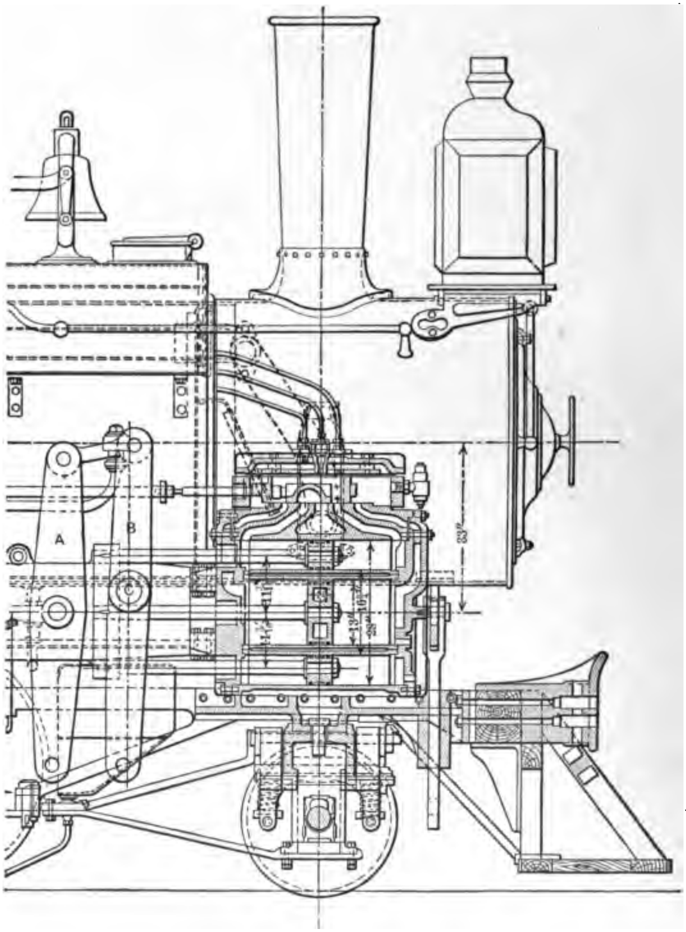


Figure 29. Front end of Johnstone's compound, showing connecting levers and annular cylinders.

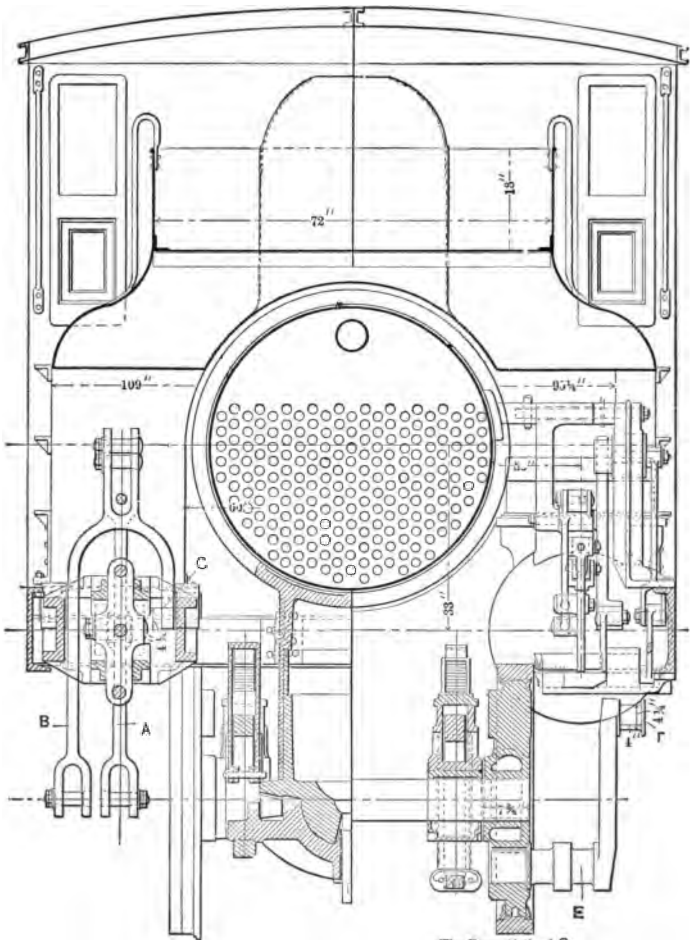


Figure 30. Cross section of Johnstone compound, showing connecting levers and both crank pins D and E.

How Dunbar would do it.

In April, 1898, Mr. J. H. Dunbar, of Youngstown, Ohio, patented the design shown in Fig. 31 for balancing the strains in the engine. As will be seen, he proposed tandem cylinders in which the pistons travel in opposite directions at the same speed, so that one will balance the other and avoid the necessity for counterweights in the driving wheels.

The low pressure cylinder is in front, and its rod connects with the top of rocker arm R. This arm is

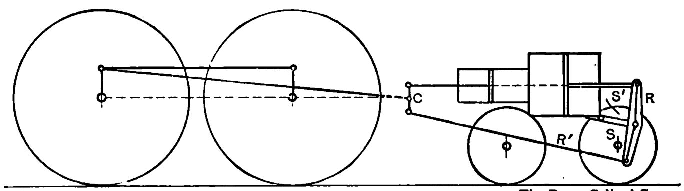


Figure 31. Dunbar's plan for balanced compound.

pivoted at its center to the radius arm S from the cylinder. The rod T connects from lower end of rocker R to the crosshead C on the high pressure piston rod. All other connections are the same as in any locomotive.

One great objection would be the arm S coming down in so near the roadbed as to strike obstructions and be deranged. None have been built that the writer knows of.

Wright's plan.

Mr. T. C. Wright patented another form of balanced compound, as shown in Fig. 32.

It embodies the walking beam or rocker idea, but in another form, the high pressure cylinder being well up on the smoke arch while the low pressure is in its usual place.

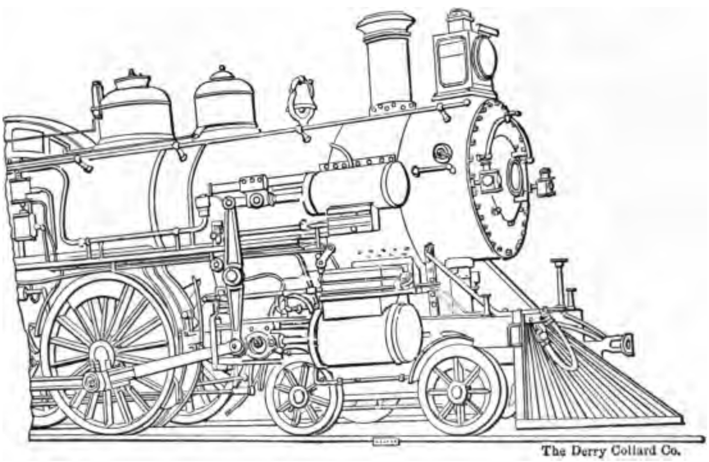


Figure 32. Wright's proposed balanced compound.

There are two crossheads with the connecting links necessary to allow for the arc or circular movement of the ends of the rocker arm. Other connections are the same as is usual in locomotive construction.

The latest design of this type is by Mr. M. N. Forney, probably the best known man in the railroad

field. The essential features as shown in Fig. 33, the operation being as follows:

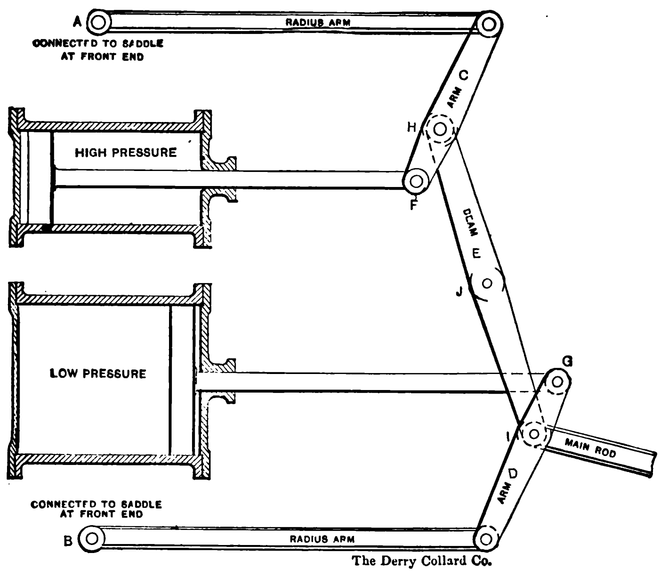


Figure 33. Forney's plan of balancing.

Radius arms are fastened to the saddle as shown, and to these are connected the arms C and D, which in turn connect to beam E. This beam is pivoted in the center and the leverage of the different arms is proportioned to give a parallel motion. The main rod connects to lower end of beam.

Locating Blows.

The location of blows or leakage of steam past the balance strips of a slide valve may be determined by placing the valves centrally over ports after blocking wheels. When the throttle is opened, any leakage by the balance strips will pass through the hole in top of valve and appear at exhaust nozzle. With double nozzles this will show which side is leaking—front end being open, of course. With a single nozzle, the sense of hearing is about the surest method of locating the side on which leakage occurs, as it is not easy to see which side the steam is from.

Cylinder cocks and exhaust nozzles will show leakage of cylinder packing rings, the cylinder cocks showing leak when steam appears at the opposite end of cylinder from which it was admitted by valve.

A blow in the rings of a piston valve of either inside or outside admission may be located by placing the valves at mid-travel, as with a slide valve, blocking wheels and opening throttle. If steam appears at the nozzle and also at the cylinder cocks, there is leakage past the packing rings.

With two-cylinder compounds, either piston or slide valves, a blow in valves may be located same as

with the simple engine, if the intercepting valve is placed in simple position so as to admit live steam to the low pressure steam chest. In this position steam will show at exhaust nozzles and cylinder cocks on either side, the same as with single expansion engines, since the high pressure steam chest receives steam direct and has a separate opening to the exhaust. Piston packing can also be tested the same as simple engines with intercepting valve as above.

In tandem compounds, a leak in the rings of the high pressure valve may be located by the same process as detailed for single expansion engines with piston valves, except that such blow will show at cylinder cocks only, since the exhaust is controlled by the low pressure valve.

The rings of the low pressure valve may be tested by blocking the engine on center on the side to be tested, with the starting valve in simple position, when steam admitted will pass around the by-pass valves of high pressure cylinder and reach the low pressure valve. If rings leak, it will show at cylinder cocks and nozzle.

Piston packing of tandem cylinders require careful testing. With the engine in simple position and steam admitted to low, any leak showing at exhaust nozzles or from opposite cylinder cock must come from low pressure piston rings of side being tested, as there is steam on both sides of high pressure piston.

To test high pressure piston rings, put engine in compound position and admit a little steam to one end of that cylinder. It can not get into low pressure except past high pressure piston, and if any shows at opposite cylinder cock of the high pressure cylinder,

at the same cylinder cock of low pressure cylinder or out of exhaust, it indicates leaky rings in high pressure piston.

The detection and location of blows in any engine is not an easy matter; but when you have two cylinders with their packing rings and a piston valve with eight rings of its own, all bunched together as in the Vauclain compound, it becomes a difficult matter, and it is very easy to call a mishap to the valve motion a "blow" and the opposite.

The main cause of this confusion is when the engine has a heavy and a light exhaust with the other two about as they should be. When you hear this, look for something wrong with your valve motion, such as a bent eccentric rod or slipped eccentric. If you don't find it here, then try to locate it in the cylinders, but it will usually be found in the motion.

The starting valve levers sometimes become bent from striking an obstruction, and this is apt to puzzle an engineer at first. The starting valve should stand central when the cylinder cock lever is in compound position. If bent, it could admit live steam to the low pressure cylinder while in compound position, making a heavy exhaust from the side having the bent lever. Try putting the lever in the extreme back position (live steam position), and the unequal exhaust will probably disappear from that side. If badly bent, this may close that side and open the other starting valve. This would give a heavy exhaust from that side with the lever in back position, and would prove that the trouble was in the starting valve. The starting valve lever should stand vertically when cylinder cock lever is in central position, and a careful examination will show

whether the trouble lies here or not. If not, then the packing rings are probably at fault, and we must determine whether the valve or piston rings are leaking.

If we have the heavy and light exhaust, and the trouble was not in the starting valve, we can locate the trouble easiest by looking at a diagram of the cylinder, as shown in Fig. 34. In reality, the valve does not lay between the cylinders as shown, but behind the cylinders. It is shown in this way for the sake of clearness in explanation. This shows the pistons nearly midstroke or with crank pin near the quarter, and the ports are open as indicated. If now we close starting valve and admit steam to high pressure cylinder, it will fill left hand end of that cylinder. Now, by reversing engine, we move the valve to the left, and we have steam in both ends of high and right hand of low pressure cylinders.

If any amount of steam blows when you raise front cylinder cock, the leak may be in rings 3 and 4, or 5 and 6 (in other words, the low pressure rings), or it may be the piston rings. To determine which, cover ports with valve and try again. If it stops, the leak is in piston rings; but if not, then rings 3, 4, 5 and 6 need attention, or a continued blow might indicate both piston and valves, but this is unlikely.

High pressure piston rings are easily tested, if the cylinder has holes for indicator; if not, it is necessary to slack the union nuts of the by-pass or live steam pipes. Keeping engine blocked in position shown, open throttle and admit steam to high pressure cylinder, starting lever being in compound or central position. If steam shows at opposite indicator hole or steam pipe, it must leak past cylinder rings.

High pressure rings.

With indicator plugs out, place valve in central position, so as to cover ports and admit steam. If any escapes, it must come from leaking high pressure rings,

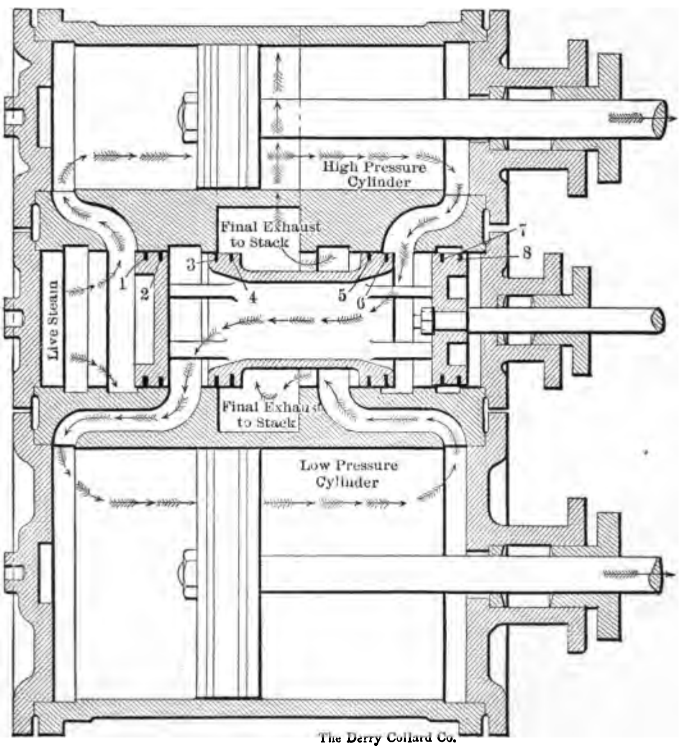


Figure 34. Cylinders and valve of Baldwin or Vauclain four-cylinder compound.

or numbers 1, 2, 7 and 8. Should it blow from one end only, it indicates the rings on that end blowing. Low pressure cylinder packing rings can be tested

by putting live steam in large cylinder through by-pass or starting valve. A leak will show at the opposite cylinder cock, as well as the exhaust pipe or nozzles.

Determining which side the blow is on seems puzzling at first, but it can be easily located with a little study. If your engine is more powerful than before, the trouble is on the side with the heavy blow, as that side is getting more steam than it should; but if it is weaker, the leak is on the side of the weak exhaust. The steam is blowing through without doing work.

The packing troubles are divided between the valve and the low pressure cylinder, the latter being far in the lead on some roads, and the cause is not always apparent. In some cases they have broken ring after ring, not averaging a week's service each, while in others they last a long time.

They did not cut in the former case, but simply went to pieces. It was credited to the surging of the low pressure piston up and down, and rings of a larger section lessened the difficulty.

Broken pieces of packing sometimes get into cylinder cocks and block them. This is pretty fair evidence that the valve packing on that side needs attention, for there are eight packing rings in the valve against two in each piston. If you are not quite sure which it is, better examine valve first, as it is easier to get out, and the trouble is probably there.

Breakdowns.

When any locomotive, simple or compound, breaks down on the road, it calls for the best judgment of the engineer. The prevailing conditions of the road must determine whether to attempt repairs, to disconnect and limp in under partial power, or to wait until he can be pushed out of the way to keep the road open.

The first law of railroading is to keep the right of way open for traffic. If the traffic is heavy, there is small chance for repairs before the next train is due, and the quickest means of getting the engine and train out of the way must be considered. In any case, it is well to understand an engine well enough to know what to do as soon as anything happens.

Two-Cylinder Compounds.

Should the break or derangement occur in high pressure cylinder so that it can not be used, it is plain that steps must be taken to get steam to low pressure cylinder. The exhaust will take care of itself, as it always goes to the stack from the low pressure cylinder.

The intercepting valve must be held in simple position, so that live steam can go to low pressure steam chest *through the reducing valve*, unless that is deranged.

If so, the engineer has a fine job of throttling on hand to prevent the large cylinder getting steam at too high pressure, and slipping wheels, breaking crank pins, or otherwise straining the engine. The high pressure valve must, of course, be blocked to cover all ports.

If the low pressure cylinder breaks, block valve in center to prevent steam getting in cylinder. Open the auxiliary exhaust for high pressure cylinder and fasten in that position. With low pressure valve blocked, it does not matter where the intercepting valve is fastened, but it is well to block in compound position.

Should anything happen to the reducing or intercepting valve, you will know it by action of engine. If engine fails to start a train in simple position, the low pressure is evidently not getting steam. Intercepting valve is probably stuck in compound position. In the Pittsburg and Baldwin two-cylinder compound this would also close the auxiliary or emergency exhaust from the high, and engine would be dead. As there is nothing automatic about this valve, it can be moved into proper position from cab, or, if connections are broken, moved and fastened by intercepting valve stem.

In other types, however, the auxiliary exhaust is separate, and would not be affected by the intercepting valve itself sticking in any position.

If you get live steam to both cylinders and an exhaust opening from each, the engine will start the proper train without difficulty. Should the intercepting valve stick in simple position, the engine would run all right, but would use too much fuel. If, however, it was not convenient to fix the intercepting valve, it would be better to run simple and burn more fuel, but

keep the road clear. The engine may also refuse to go in compound from the auxiliary or high pressure exhaust valve sticking and letting high pressure exhaust out of the stacks, instead of into low pressure steam chest. This, of course, applies only to those having a separate intercepting and exhaust valve, as the Schenectady, Richmond and Rhode Island.

Repairs.

While, as a rule, any mechanic who can repair a simple locomotive will have no difficulty in keeping up a compound, after they get over the idea that they are hard to understand, they will soon learn what parts require most attention and what repairs are needed by them.

On some types the crosshead wears quite rapidly and needs re-tinning. This can be done with little trouble by a coppersmith or any one trained for it. Heat the crosshead until it will melt solder; clean and use muriatic acid of the strength used by tinsmiths in soldering. Go over it lightly with solder which would melt and adhere. Place a piece of iron so as to regulate thickness, and then pour block tin against the surface covered with solder. It will unite and be ready for planing to size. A sharp planer tool is needed to prevent its digging in and tearing off the tin.

Piston packing is treated the same as in simple engines, the low pressure requiring the most attention.

Piston valve rings wear and break in some cases and give little trouble in others. Before they get to leaking badly, the bushing should be rebored and new rings put into the valve. Sometimes the rings alone will stop the trouble and save the reboring of bushing.

Reboring valve bushings.

When the bushing becomes large from frequent reborings, a new valve should be put in, so as to leave as little space as possible between valve body and bushing.

The boring can be done by any good portable boring bar. A very convenient one is made by the Baldwin Works, and the H. B. Underwood Co., also of Philadelphia, make a specialty of tools of this kind.

This compares with the facing of a slide valve seat, and requires about the same time.

When the bushings have been bored as thin as is considered advisable, they can be removed the easiest by simply splitting with a narrow cape chisel. They are nothing but scrap iron when removed, and the quickest way of removing is the best. This is much better than pulling them out with draw screws.

Tandems of any type are not pleasant subjects for quick repair on the road. It generally means a case of disconnecting the injured side, and this means taking down all of the side rods on the other side, as explained in the section under disconnecting.

With the size of locomotives in use to-day, this is about all that can be done on the road in any case, but when it comes to roundhouse repairs, the manner of connecting the cylinders has quite a bearing on the case, as will be seen under that heading.

With the cylinders bolted closely together, as in the Schenectady tandem, it is not an easy job to get at the pistons for replacing the packing rings when it becomes necessary, even though hand hole plates are sometimes put on the cylinders for that purpose.

You have your choice of two ways: Taking piston rod out of crosshead, unbolting high pressure cylinder

and valve chest and removing, which will pull low pressure piston and rod out of cylinder. Then the intermediate head can be removed and the high pressure piston pulled out of the cylinder. All this must be done without bending the piston rod and is a job requiring care and good crane facilities. The way intended by the builders is as follows:

Take off front head of high pressure cylinder and remove piston head. Disconnect the main rod from crosshead, remove back head of low pressure cylinder and with it the guides, crosshead and a special connection to guide yoke.

Even this is something of a job with the ordinary roundhouse facilities.

The Baldwin tandem has a crane on each side of the smoke arch for this purpose.

The method of examining the pistons of the Colvin-Wightman is described in the section relating to that engine and need not be repeated.

In conclusion, see that starting valves are right, levers not bent, cylinder cocks free and in good condition, and you will have little more trouble in taking care of compound than simple engines.

Reducing Valves.

These are now used on all two-cylinder compounds built in this country, but not in Europe. As shown in the historical sketch, they were first conceived by Mallet in 1879, but he did not make one that worked well in practice. The first that we know of was applied to compound locomotives by Henry F. Colvin, of Philadelphia, and was used by permission on the Rhode Island compounds in 1890. A similar device had been used in hydraulic work years before, but had been forgotten by every one except the patent office, so that the patent only covered its application to a locomotive.

It is a very simple device and does not depend on springs or other mechanism—merely on the action of the steam itself. Taking the case of a two-cylinder compound with cylinders 20 and 30 inches in diameter, and we have a ratio of 1 to 2¼. That is, the low pressure piston contains 2¼ times the area in square inches of the high pressure piston. A table of circles shows the area of the high pressure cylinder to be 314.16 square inches, and the low pressure cylinder 706.86 square inches. Dividing the latter by the former we get 2¼, proving the ratio of the cylinders to be 1 to 2¼.

In working live steam in both cylinders, as is done

with the engine in simple position, it will be readily seen that if they both receive full boiler pressure, the low pressure cylinder will have 2¼ times the power of the high, and the engine would slip badly and probably damage itself considerably. If, however, we can reduce the pressure of steam in the low pressure cylinder so that it will do no more than its share of the work, we have an engine which will work well as a simple engine as long as necessary.

The first compounds of the two-cylinder type (and this is the practice in Europe to-day) accomplished this reduction by passing all the live steam for the low pressure cylinder through a small pipe, to reduce its pressure by wire-drawing it. This gives no uniformity in the pressure obtained, and if the engine does not start at once, the pressure accumulates until it is full boiler pressure. It also prevents running simple as long as desired, for these engines go into compound automatically as soon as receiver pressure accumulates.

The reducing valve used on the Baldwin two-cylinder compound gives a good illustration of the principle involved and is shown separately by Fig. 35, without any of the attachments or connections. The steam passage from the boiler is at the right and acts against the end of small piston "A," which represents the high pressure cylinder. In other words, if the area of "A" is 10 square inches the area of "B" must be 2¼ times this or 22½ square inches.

Steam at 180 pounds, we will say, acts against small end, and forces the valve open, escaping into the receiver as indicated by arrows.

The other end of large piston is open to whatever pressure exists in the receiver, and as soon as this ex-

ceeds 80 pounds (because $2\frac{1}{4}$ times 80 is 180) the reducing valve is forced to the right again. This throttles or wire-draws the steam until just enough gets through to keep the receiver pressure at 80 pounds.

It is simply a case of equalizing total pressures, as a few figures will make plain. Assuming as before that the area of "A" is 10 square inches and the steam pressure 180 pounds, then the total pressure against "A" will be 1,800 pounds, forcing it to the left. The area of "B" is $22\frac{1}{2}$ square inches, and this multiplied by the receiver pressure of 80 pounds gives the same result of 1,800 pounds, proving that they are balanced,

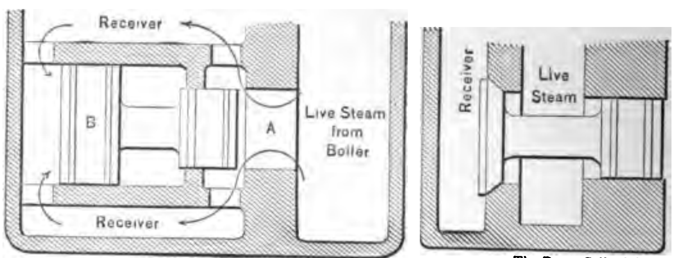


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Figure 35 Two types of reducing valves. Figure 36.

and that the valve will stay in the same position as long as these conditions remain.

Suppose the engine slows down from some cause or other and uses less steam, the receiver pressure rises up to say 82 pounds. Then the total pressure on "B" is $22\frac{1}{2}$ times 82, or 1,845 pounds. This overbalances the pressure of 1,800 pounds on the other end, and the valve moves to the right, shutting off some of the steam passing through until the total pressure on both ends of valve is equal. Should the engine stall,

the pressure would accumulate in the receiver and close the valve entirely. As soon as engine starts or receiver pressure is relieved, it will open and go to work as before.

As will be seen, the action is simple, positive and automatic. The only thing that can interfere with it is the breaking of the valve or its packing rings, or its becoming stuck from dirt or lack of attention. The principle involved is a very neat application of balancing of pressures, and it is one of the essential features of a two-cylinder compound of to-day.

There are several forms of this in use, as can be seen from a little study of the intercepting valve arrangements of the different types of engines. One form is shown in Fig. 36, in which there is a conical seat valve at one end (properly guided of course, although not shown complete in this) and packing rings at the other. This reduces the number of packing rings by half and makes a very neat form of valve.

The steam in this case comes in between the heads of the valve, and the outer end is open to the atmosphere, to prevent an accumulation of pressure behind the piston should any leak past the rings.

Drifting.

Every locomotive, whether simple or compound, would be better if provided with proper "drifting valves." When running down grades without steam and reverse lever in forward motion, the valves move the same as though steam were being used. As there is no steam in the chest, the movement of the piston away from the head draws down what air there is in chest and ports and produces a partial vacuum. That is why air valves were put on steam chest. They allow air to be drawn in from outside and prevent this vacuum, as it retards the piston by acting as back pressure.

When the piston returns, the air valve closes and the air drawn is forced out of the exhaust in place of steam, but it blasts the fire just as steam would, and burns coal when there is no need of it.

With the reverse lever full forward, more air is admitted to cylinders than when hooked up, just as more steam is admitted, all of which has to be forced out, and blasts the fire more. But with the reverse lever in this position, the exhaust closes late, causing very little compression.

If we hook up the reverse lever and shorten cut-off,

we admit less air to be forced out, but we close the exhaust much earlier, increasing compression and retarding the free running of the engine.

This blasting of the fire is not particularly noticed on simple engines, because we have always had it, and the cylinders are small as compared with the low pressure of a compound. The volume of air forced out the stack by a 35-inch piston is four times that handled by a 17½-inch cylinder of the same stroke. And there are 35-inch low pressure cylinders in daily service with larger strokes than it is customary to give 18-inch cylinders.

This explains why simple engines very often proved more economical than compounds on mountain roads when the latter first began to be tried in this country. Take a two-cylinder compound, 20-inch high and 30-inch low pressure cylinders equal to an 18-inch simple engine, as an example. If not overloaded, it would work up the mountains much more economically than a simple engine, but in drifting down the other side, the low pressure cylinder would be pumping 2¾ times as much air out the exhaust nozzles as one cylinder of the simple engine and the high pressure cylinder nearly 25 per cent. more than the other cylinder, or a total of at least three times that of a simple engine. This would blast the fire, so that it was said "the compounds burned more coal going down than they did climbing the mountain," which was, of course, exaggerated But this extra blasting of the fire was often enough to throw the balance of economy on the side of the simple engine.

This led to the introduction of the "over-pass" or "drifting valve" by the Richmond Locomotive Works,

they being the first to apply a remedy for the evil. Their type of valve is shown and explained with their compound, and others are using devices to accomplish the same object. All, however, have the objection of adding more or less clearance to the cylinder, except the plan used on the Colvin-Wightman tandem of raising the balance plate of low pressure valve. This does not alter clearance in the least, and yet gives the largest "over-pass" area—the full area of port.

The main trouble with most of the drifting valves is the insufficient areas allowed. In one case it was practically but one square inch, and they were abandoned as being useless—which wasn't far from right, considering their size. It is almost safe to say none of them are large enough, referring now to the regular valves used.

Tests have proved that some of the recent engines will not run down hill at any but slow speed, owing to the excessive compression in low pressure cylinder. Taking out the over-pass valves and leaving the area free of obstruction doubled the speed at which they would run, which shows they were cramped before. Taking down low pressure rods and letting the high pressure side run free gave any speed desired.

These tests simply prove that any engine needs an over-pass device; the larger the cylinder the greater the necessity.

Last, but not least in the eyes of the engineman, is the tendency of the engine to buck and jump when running down hill, due to the air pump action of the large cylinder. This produces a disagreeable thumping and a more or less violent longitudinal oscillation, known as surging.

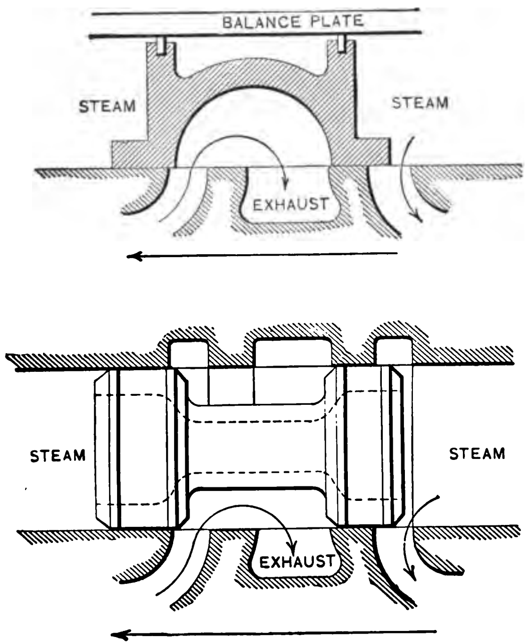
Valve Motion.

Most of the compound locomotives are now using piston valves, and as these seem to puzzle many engineers, they will be made as clear as possible. Practically speaking, they are only a round or cylindrical form of the D slide valve, the most puzzling part being that some of them admit steam at the center or where the D slide valve usually exhausts.

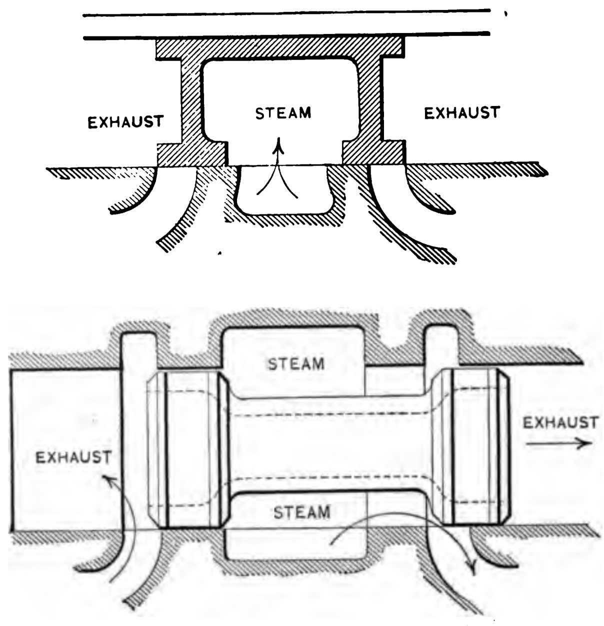
The only difference this makes is that the valves have to be set so as to move opposite to the piston, instead of with it, as with outside admission. Fig. 37 makes this clear. First is a common D slide valve, moving with the piston to open port wider as piston travels to left. Below is a piston valve with outside admission, which is the same in action. There is also an inside admission piston valve, and also indicates plainly that the valve must move opposite to piston.

It is the inside and outside admission that is responsible for the different valve gear connection found on piston valve engines, and which is sometimes hard for the repair man to get accustomed to.

Many inside admission valve engines use a direct motion—that is, the motion of link drives valve without the use of a rocker arm, as is generally used on loco-



Outside admission valves.



Inside admission valves.

Figure 37. Slide and piston valves with inside and outside admission.

motive. Where it is used, the link drives the bottom arm of rocker one way, which, of course, forces top of rocker in the opposite direction. This is called indirect motion. Either can be used with any kind of valve, but the outside admission D slide valve almost invariably uses the rocker or indirect motion. The type used affects the setting of the eccentrics, as will be seen.

Fig. 38 gives an outline of the regular valve motion with rocker. Note that crank pin and larger part of eccentrics are on the same side of axle, and that the valve will move in the same direction as the piston.

If now we leave out the rocker and drive direct from top of link, we move the valve the other way (or opposite piston), and must have either an inside admission valve, as shown in Fig. 37, or crossed ports, as are used in the high pressure cylinder of the Schenectady tandem.

The direct motion can, however, be used with outside admission valves by simply shifting both eccentrics just half way round the axle, keeping them exactly the same with reference to each other. Where both eccentrics are cast together, and is being done in some places, they would remain in correct positions. This brings them into position shown by Fig. 39, with eccentric rods crossed, and the eccentrics on opposite side of axle from crank pin. An outside admission valve connected direct to top of this link will move with the piston and act just as it did with the rocker arm shown before.

In the same way, an inside admission valve can be used with this if we put on a rocker, as shown in Fig. 39, or an outside admission without it.

This can all be summed up in a few words that

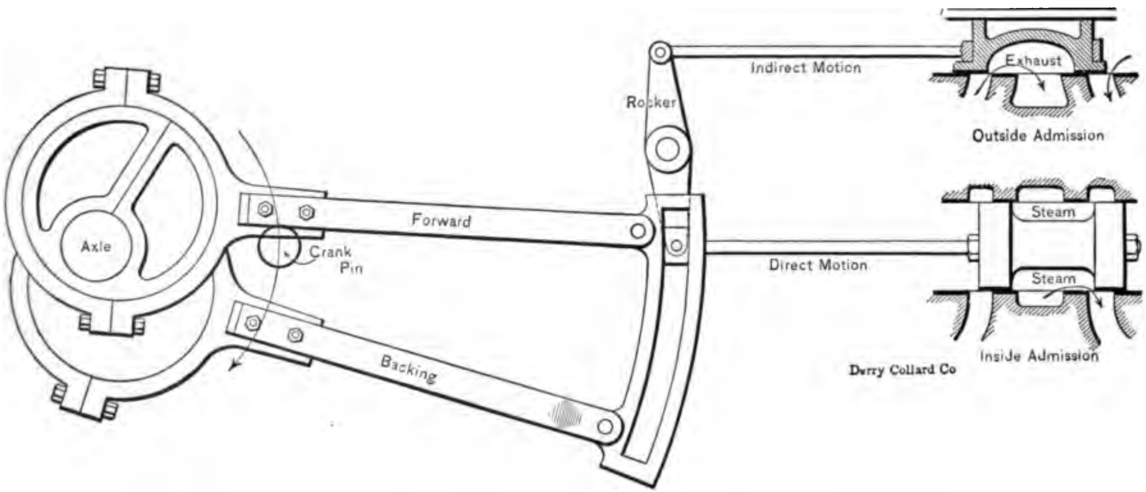


Figure 38. Valve motion as generally made. Shows how rocker allows use of outside admission valve, and how inside admission can be used without it.

will enable us to tell whether an engine has inside or outside admission valves, by a careful look at the eccentrics and rocker, if there is any.

Be sure whether the rocker reverses the motion or not. A regular rocker arm has top and bottom connection with bearing in center, and *reverses the motion.* Some transmission rockers simply pass the motion along without reversing it. See which is used on your engine.

When the crank pin and eccentrics are together and the motion is reversed by a rocker arm, the engine has an outside admission valve.

With conditions the same as above, but no rocker to reverse motion, there is an inside admission valve.

If eccentrics and crank pin are on opposite sides of axle and there is a rocker arm, the valve has inside admission.

These three conditions are those generally met with, but there is one more combination possible; that is, eccentrics and crank pin on opposite sides of axle and no reversal of motion by rocker arm. This would mean an outside admission valve.

By carefully noting which of these conditions exist, the setting of the valve is not such a difficult matter, and this seems to be the proper place to emphasize the advisability of setting valves for the point of cut-off at which the engine is used the most. The practice of setting valves at full stroke, and then resetting at running cut-off, is now considered by many as a relic of the dark ages of railroading.

The setting of slide valves can be done easiest with the steam chest cover off, when the lead at each end and uniformity of travel can be closely examined.

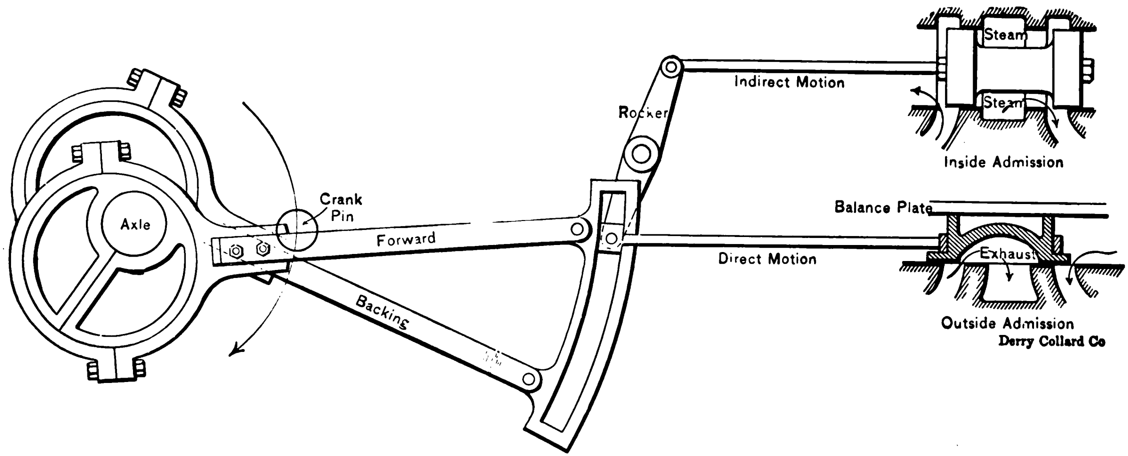


Figure 39. Valve motion as made for inside admission piston valves. Shows how outside admission valve can be used without rocker.

In practice the valve stem is marked with center punch for different position of valve, so that it is unnecessary to remove cover.

With piston valves we can only get at the front head of valve chamber, and that is not always entirely satisfactory. Most piston valve engines are provided with "peep" holes tapped into side of steam chest, so the edge of valve ring can be seen. The reflected light of a candle is sometimes used (a small mirror being fixed behind the candle to throw the light inside). For night work, the candle—if no better light is at hand—is used to light the valve chamber, so the position of valves can be seen at the peep holes.

After getting the desired lead at one end, with crank on center, the wheels are pinched or turned by more modern devices until the crank is on other center. If lead is correct here, the valve is right. Should lead be unequal, it can be divided up between the ends; and if this is too much, eccentrics must be moved nearer to a *vertical position without regard to crank pin.* If more lead is wanted, move away from the vertical. This holds true with any motion.

If you wish to consider the crank pin, you must study Figs. 38 and 39; but as you then have to remember all the details of the motion, it is better to forget the crank pin, and with the crank pin on center consider the eccentrics in connection with a vertical or plumb line through center of driving wheel. This, of course, supposes that the eccentrics are on the right side of axle to give desired motion to valve, and is only used to increase or decrease lead as desired.

Disconnecting.

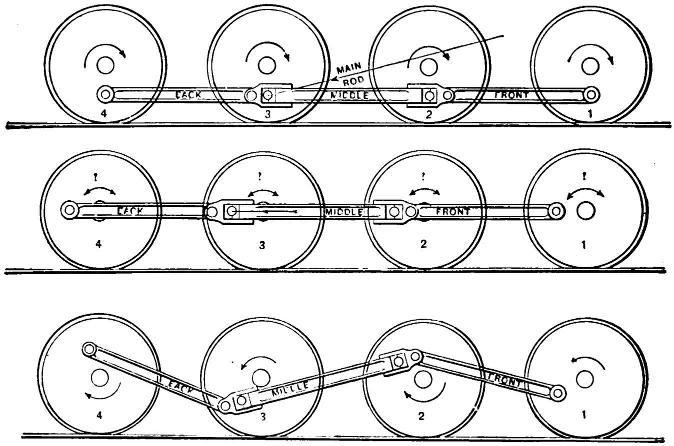
Any engine, whether simple or compound, is liable to require disconnecting in case of broken side or connecting rods, and as it is a disputed point as to whether to take down rods on both sides or not, it will be considered carefully, as the question is important.

The blowing out of a cylinder head was formerly considered as sufficient excuse for taking down side and connecting rods, but many are abandoning this practice and letting the piston run in the cylinder, if it can be done without injury, as is usually the case. It is then simply necessary to block the valve in central position, so as to keep steam out of the cylinder, and to see that cylinder is well lubricated to prevent cutting. It is, of course, advisable to cover the end of cylinder with boards or canvas to keep out the dirt. This is easier than taking down rods, especially on any of the larger engines of to-day, and is better in every way, making less work for the repair men at the shop.

A broken rod is another question, however, and should be thought out carefully. After you have the reasons well fixed in your mind, there will never be any hesitation as to what to do. This means that you can get to work as soon as the engine stops, and get

engine ready to run on one side or be towed, as the case may be. Time saved in this way means less delay to trains, and is appreciated by the transportation department as well as your own.

The illustrations show an eight-coupled engine with the rods as usually connected. From these you can readily see what to do with a ten-wheel mogul or



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Figures 40, 41 and 42. Possible action of side rods with other side disconnected.

eight-wheel engine, by giving the matter a few minutes' thought.

When the rods are all in place, those on one side will be on the center, and the others at either upper or lower quarter. The rods on the center are practically idle at that instant and exert no power, nor do they turn the wheels; the rods on the quarter are doing the

work. As they move off the center, both sides are at work until the other side gets on the center, when the conditions are reversed. If we take off the rods which are on the center, the others will force the wheels around until they reach the center, and if the engine is barely moving (or has no momentum), here it will stop. Now, with the pressure against the piston and the rods in this position, as shown in Fig. 41, there is nothing to force the wheels in any particular direction, but they can turn one way just as easily as the other. If they all decided to turn the same way, it would not be so bad, but they sometimes have different ideas on the subject and act as shown in Fig. 42, which is what shears off crank pins and breaks rods.

The writer recalls one case in which the engineer left all the rods on one side and none on the other and ran the engine home without difficulty, but in putting it on the turn-table, with its usual backing and going ahead, the side rods took different directions and did much damage. This would have been prevented had the rods been taken down, proving that it is always better to be on the safe side.

The backbone of the whole matter is to remember that the main rod is the only one that can run one-sided with safety. Also, that in every case corresponding rods on each side must come down. If one main rod breaks and does not injure any of the other rods, nothing need be taken down except the broken rod, as all the wheels will be forced to turn by the side rods, all being in place. If a side rod breaks on an eight-wheeler, it is simply necessary to take down the broken rod and the one opposite to it, as these rods have no others coupled to or dependent on them. In the case

of a ten-wheeler, mogul, consolidation, or other types of coupled engines, the dependent rods must be considered.

With the arrangement shown, the central side rod is solid between the pins of wheels 2 and 3, while the other rods are dependent on the middle being coupled to it and to the crank pins at other end.

If front rod breaks on one side, it is necessary to take down both front rods; all the others can remain. The same is true of the back side rod, as in either case the remaining rods drive all the wheels on both sides except the pair directly affected by the broken rod. A break in the middle rod, however, means taking down all the side rods on *both sides*, as there would be nothing to drive either front or back, and it would not be safe to leave any rods up on the other side, for the reason previously shown.

A break in front or back rods would leave three pairs of wheels driving, while a break in the center rod would cut out all except the main drivers, making it a "single" engine, as this type is sometimes called.

If we cover wheel 1 and only consider 2, 3 and 4, we have all the conditions of a six coupled engine, and the same conditions apply as with the eight coupled. Leaving out wheel number 4, as well as number 1, and we have the driving wheels of the Atlantic type, which is the same as the regular eight-wheel engine, so far as taking down rods is concerned.

By remembering that:—

Main rod only can be run one sided with safety, and

Corresponding side rods on both sides must come down, you will have no trouble in handling any break that may occur.

Power of Compound Locomotives.

The Baldwin Locomotive Works use this formula for finding the tractive or pulling power of their Vauclain compounds, when

C = Diameter of high pressure cylinder in inches.
c = Diameter of low pressure cylinder in inches.
S = Stroke of pistons in inches.
P = Boiler pressure in pounds per square inch.
D = Diameter of driving wheels in inches.
T = Tractive power in pounds.

And $T = \frac{C^2 \times S \times \frac{2}{3}P}{D} + \frac{c^2 \times S \times \frac{1}{4}P}{D}$

Those who prefer this in the form of a rule may understand the plain English of it better.

RULE: Square the diameter of the high pressure cylinder by multiplying it by itself. Multiply this by the stroke in inches. Multiply this product by two-thirds of the boiler pressure, and divide the whole thing by the diameter of the driving wheel in inches. This gives the power of the high pressure cylinders.

Then repeat these calculations for the low pres-

sure cylinder, with the exception that you use $\frac{1}{4}$ the boiler pressure instead of $\frac{2}{3}$, as in the case of the high pressure cylinder. Add the power of both high and low pressure cylinders together, and you have the power of the engine.

Take an engine of this type with cylinders 15 and 25 inches by 26-inch stroke, with 80-inch wheels and 200 pounds of steam—a modern high speed engine for passenger service.

Squaring 15, we have 15 times 15, or 225. Multiplying this by 26 gives 5,850. Two-thirds of the boiler pressure is 133⅓ pounds, so multiply 5,850 by 133⅓ and get 780,000, to be divided by 80, the diameter of drivers in inches. This gives 9,750 pounds draw bar pull for the high pressure cylinders alone.

Repeating this with the low pressure cylinders, we have 25 times 25, or 625. This multiplied by 26 inches stroke is 16,250. One-quarter boiler pressure is 50 pounds, so this is multiplied by 50, giving 812,500, which, divided by 80, is 10,156 pounds for the low pressure cylinders, or a total of 19,906 pounds.

Done in the style shown by formula, it looks like this:

$$\frac{225 \times 26 \times 133\frac{1}{3}}{80} + \frac{625 \times 26 \times 50}{80}$$

which reduces to 9,750 plus 10,156, or a total of 19,906, the same as before. By following the rule as outlined by the example you can readily figure out the tractive power of any compound of this type.

For two-cylinder compounds the rule and formula are much simpler, as you have but two cylinders to deal with, as in a simple engine, but under different conditions. Using the same letters as before we have:

Power of two-cylinder compounds.

C=Diameter of high pressure cylinder in inches.
S=Stroke of piston in inches.
P=Boiler pressure in pounds per square inch.
D=Diameter of driving wheels in inches.
T=Tractive power in pounds.

The low pressure cylinder is not considered in this formula, being offset by leaving out the back pressure on the high, as this is all the steam received by low pressure cylinder when working compound.

The formula is $\frac{C^2 \times S \times \frac{2}{3}P}{D} = T$

This can also be worked in the plain English way as follows:

RULE: Square diameter of high pressure cylinder by multiplying by itself as before. Multiply by stroke in inches and by two-thirds boiler pressure. Divide the whole product by the diameter of drivers in inches, and the result is the tractive power in pounds.

As an example of this, take a 22-inch high pressure cylinder with 26-inch stroke, 200 pounds boiler pressure and 80-inch driving wheels as before. The low pressure cylinder would probably be 33 inches, but that need not be considered, as they are proportioned for the steam pressure and the work in hand.

Multiplying 22 by 22 gives 484, and this multiplied by 26-inch stroke is 12,584. Two-thirds boiler pressure is 133⅓ before, and multiplying by this gives 1,667,866, to be divided by 80 as before. This shows the tractive power to be 20,973 pounds, or a little more than the Baldwin type just calculated, and also indicates that they are almost matched with cylinders of this size. That is, a 15 and 25-inch Vauclain is nearly as powerful as a two-cylinder compound having a 22-

inch high pressure cylinder. This relation will be mentioned later, showing how they can be compared without much figuring.

It will also be noted that the rule for the two-cylinder compound is the same as for the high pressure cylinders of the Vauclain type of engine. In neither can we use the boiler pressure, but only that part of it that is effective in the cylinder. In order to have them of equal power, it is necessary to have the high pressure cylinder of the two-cylinder type enough larger to make up for the low pressure cylinders of the other.

To make this complete and get a thorough understanding of the subject, it will be best to touch briefly on the power of simple engines and show how it is obtained. We can then find a way of guessing pretty close on the power of any compound as compared with the simple engine.

Using the same letters as for the two-cylinder compound the same rule applies, except that the mean effective pressure is used instead of ⅔ of the boiler pressure. This makes the rule as follows:

RULE: Square cylinder diameter in inches, multiply by stroke in inches and by mean effective pressure. Divide this product by the diameter of driving wheel in inches.

The mean effective pressure is generally taken at 85 per cent. of the boiler pressure. Some use 80 per cent.; but as the engine is supposed to be moving very slowly, it is probable that 85 per cent. of the boiler pressure finds its way into the cylinder to do effective work.

Taking the same engine as before, except that the

cylinders are 20 instead of 22 inches in diameter, we go through with the calculations once more. Squaring 20 we get 400, multiplying by 26 we have 10,400. Eighty-five per cent. of 200 pounds is 170 pounds as mean effective pressure, so multiply by this and the result is 1,768,000. Divide this by the diameter of driving wheel, or 80 inches, and the tractive power proves to be 22,100 pounds, or a little more than either of the others, but still fairly close to them—close enough that it gives us a basis to work on for our comparisons, or to guess with.

Starting with the simple engine and assuming the same stroke, boiler pressure and driving wheels, we find that by adding ten per cent. to the diameter of the cylinder we have the diameter of the high pressure cylinder for a two-cylinder compound of practically the same power (about 5 per cent. less in this case), ten per cent. of 20 being 2, and 20 plus 2 giving the 22-inch high pressure cylinder. If you care to go further, you will generally find the low pressure cylinder about 1½ times as large as the high pressure, or 33 inches in this case. This gives a cylinder ratio of 2¼ to 1, which seems to be about right for most cases. This means that the area of the low pressure piston is 2¼ times that of the high, which you can prove by consulting a table of areas of circles. There you find the area of a 22-inch circle to be 380.13 square inches and of a 33-inch circle 855.30 square inches, or 2¼ times as much.

With the Vauclain engine we have been considering the sum of their cylinder diameters is 25 plus 15, or 40 inches, and half this is the diameter of the cylinder of a simple engine of about the same power.

A rough and ready comparison.

It can also be noted that the high pressure cylinder of the Vauclain engine is ¾ the diameter of the simple engine's cylinder, and this gives us another point to guess from in these comparisons.

Having a Vauclain engine of 15 and 25-inch cylinders and wishing to know about what size simple engine it can be compared with, we add the two diameters together, and half of that is the diameter of the cylinder for the simple engine. In this case this engine is 11 per cent. more powerful than the Vauclain, and the variation will usually be less than this.

On the other hand, if we wish to know what size Vauclain will compare with a simple engine of 20-inch cylinder, we take ¾ of 20, or 15, and call that the high pressure cylinder. Then as twice 20 is 40, and the difference between 15 and 40 is 25, that is the diameter of the low pressure cylinder for an engine of this type to about compare with the 20-inch simple engine.

With a 22-inch high pressure cylinder in a two-cylinder compound, it is only necessary to divide the high pressure cylinder by 11 and multiply the result by 10, as this is the easiest way of taking the right percentage in this case.

It must not be understood for a moment that this is given as an accurate way of making comparisons, for exact calculations of each case is the only correct way to do this. It could be figured closer in the case of the two-cylinder compound by taking odd figures; but 10 per cent. is a very handy figure, easily remembered, and better, if we thoroughly understand that it is not quite correct.

This makes a very handy way of coming somewhere near the comparative power of the different types

of engines with very few figures and little trouble. Some of the comparisons may not come quite as close as those we have made, but few of them are out enough to make much difference to the engineer, who merely wants to know about how much he ought to expect from the engine in question. Most of them will be closer.

The following tables have been made from the data received from different builders, and will serve to show how the engines compare on the average and how far out the rough rules for guessing bring you.

The Baldwin Works use the following table in comparing their Vauclain compounds with simple engines:

DIAMETER OF CYLINDERS.

Single Expansion.			Compound.			
140 lbs. Pressure	160 lbs. Pressure	180 lbs. Pressure	180 lbs. Pressure.		200 lbs. Pressure.	
			H. P.	L. P.	H. P.	L. P.
10½	10	9½	7	12	6½	11
11½	11	10½	7½	13	7	12
13	12	11	8½	14	7½	13
14	13	12	9	15	8½	14
15	14	13	9½	16	9	15
16	15	14	10	17	9½	16
17	16	15	11	18	10	17
18	17	16	11½	19	11	18
19	18	17	12	20	11½	19
19½	18½	17½	12½	21	12	20
20½	19	18	13	22	12½	21
21½	20	19	13½	23	13	22
22½	21	20	14	24	13½	23
23½	22	20½	15	25	14	24
24½	23	21½	15½	26	15	25

Baldwin and Richmond ratios.

The Baldwin Works' ratio for two-cylinder compounds is also 2½ to 1, as near as may be, and they use the following table:

Simple Engine.	Compound.	
12-inch	13½ H. P.	21½ L. P.
13 "	14½ "	23 "
14 "	16 "	25½ "
15 "	17 "	27 "
16 "	18 "	28½ "
17 "	19 "	30 "
18 "	20 "	31½—32 "
19 "	21½ "	34 "
20 "	22½ "	35½ "
21 "	23½ "	37 "
22 "	24½ "	39 "

The Richmond Works' practice in designing their two-cylinder compounds is to add 20 per cent. to the area of the cylinder of any given simple engine and take this for the area of the high pressure cylinder of the compound. The low pressure cylinder was then made as near 2½ times this area as possible, with figures in even half inches.

Their table is:

Simple Engine.	Compound.	
16-inch	17½ H. P.	28 L. P.
17 "	18½ "	29½ "
18 "	20 "	31½ or 32 "
19 "	21 "	33 "
20 "	22 "	35 "
21 "	23 "	36½ "
22 "	24 "	38 "
23 "	25 "	40 "
24 "	26½ "	41½ "

More cylinder ratios.

The Rhode Island Works use a ratio of 2½ to 1, as nearly as can be done with even figures, and use this comparison

Simple Engine.	Compound.	
	H. P.	L. P.
16-inch	17	27
17 "	18½	29½
18 "	19½	31
19 "	20½	32½
20 "	22	35
21 "	23	36½
22 "	24	38

The Schenectady Works use a ratio of from 1 to 2.25 to 1 to 2.4, which would give the following table:

Simple Engine.	Compound.					
16-inch	18	H. P.	27	to 28	L. P.
17 "	19	"	28½	" 29½	"
18 "	20	"	30	" 31	"
19 "	21½	"	32¼	" 33¼	"
20 "	22½	"	33¾	" 35	"
21 "	23½	"	35¼	" 36½	"
22 "	24½	"	36¾	" 38	"

Practical Notes.

From a practical standpoint, the compound locomotive should be capable of running simple or compound at the will of the engineer, who will, of course, only use it simple in starting or in getting a train over a bad part of the road, to save doubling or the use of a helper. It can also be used simple in switching work to advantage. He will remember that it is saving fuel only in the compound position, and will run it there as much as possible, but he can judge when to use simple and when compound better than any automatic device which was ever built.

It should also run in simple position as economically as a simple engine of the same class (which very few compounds do, owing to a large extent to the extra amount of fuel burned while drifting). This is on account of the large low pressure piston acting as a blower, although this difficulty is being obviated to some extent by the use of by-pass or drifting valves, which allow the air to pass from side of the piston to the other, instead of out the stack. These are usually too small to be as effective as necessary, and in nearly every case add considerable clearance to the cylinder. Last, but by no means least, the repairs should be no higher than on a simple engine in the same service.

About "nosing around."

There is an impression among many that unless a compound engine is more powerful or faster than a simple engine, it is a failure, overlooking the fact that it is designed for doing a given amount of work more economically than a simple engine, without regard to its tractive power or speed. A compound locomotive may easily be both faster and more powerful than a simple engine of about the same size, for since it uses less fuel and water the same boiler will do more with the compound cylinders than in the other case. No one claims, however, that compounds are always more economical than simple engines, as there are many cases where the reverse is true, due either to the design of the engine or to conditions of service which work against it. The cost of repairs should also be counted when summing up the true economy of any locomotive, and there have been cases where this more than balanced the saving in fuel.

Two-cylinder compounds are sometimes charged with "nosing around," due to working with greater power on one side than the other; but when we consider that a simple engine is always working one-sided, as it develops the maximum power first on one side and then on the other, this would not seem to hold.

The fact that they develop more power in working simple than compound is used as an evidence that the reducing valve does not reduce the steam as it should, so that the low gets more than its proper proportion of steam; but when we stop to think that in the simple position the high pressure cylinder is exhausting direct to the stack and is relieved of its back pressure (which practically adds so much to the forward pressure, and consequently to the power of the engine), we see that

the reducing valve is not at fault. This also shows why the engine will start a train better or haul more cars over a bad hill if worked in simple position.

Many two-cylinder compounds have an oil pipe to intercepting valve, as well as the cylinders. Where this is connected up to the sight-feed lubricator, it is often given one-half the amount fed to the high pressure cylinder.

The amount of lubrication needed varies with the engine and the service. Some types claim greater oil efficiency than a simple engine, but most of them admit the necessity for more oil than the simple. More or larger cylinders or both would seem to demand more lubrication. In any case, there should be enough.

Some advise 6 to 10 drops per minute on the high pressure side only when running with steam. When drifting, this should be regulated so the low pressure receives the most.

A report from a performance sheet shows 48.30 miles to one pint of valve oil, 29.56 miles to one pint of engine oil. This for a consolidation engine, weighing 153,000 pounds.

A good engineer who has handled many compounds in heavy freight service on a rather hilly road advocates 2½ pints of valve oil per 100 miles.

Don't be too anxious to take all the thump out of the engine, especially if it is an old one. A simple engine will often heat up when we try to get them adjusted "too fine," and engineers who handle compounds right along credit them with being even more balky in this respect. Solid end side rods have done away with much of this trouble.

What a good engineer will do.

Nearly every one advises the use of more oil in the cylinders than with a simple engine. At least, many claim that they require more, and in view of the larger cylinders used for the low pressure, this is not surprising. While those who rather save a pint of oil than a ton of coal, put this down as a black mark against the compound, we should not lose sight of the fact that the saving of a ton of coal will buy all the extra oil needed for a dozen engines. This same philosophy will also often apply in the case of simple engines.

A good engineer will run a compound just as he does a simple engine, that is, work them both with the reverse lever and throttle where they will do the most work with the least fuel.

Some advise the frequent opening of cylinder cocks, especially in cold weather.

If drifting down hill, it is generally best to have throttle open enough to show at cylinder cocks unless engine is provided with ample by-pass valves.

Engineers who have been used to simple engines are sometimes misled by the difference in the number of exhausts from a two-cylinder compound, and think the engine is about to stall, when a simple engine at the same speed would not worry them in the least. The exhausts, occurring only half as often, are deceptive and sound as though each was the last, when in reality the engine may get along very nicely. This will be soon learned, however, and the engine not thrown into simple unless the speed falls to about four miles an hour. Then throw into compound again as soon as it has picked up to eight miles an hour.

On some long grades it may be found best to

This sometimes helps on long grades.

change from one to the other frequently, running compound whenever it can be done without danger of stalling.

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